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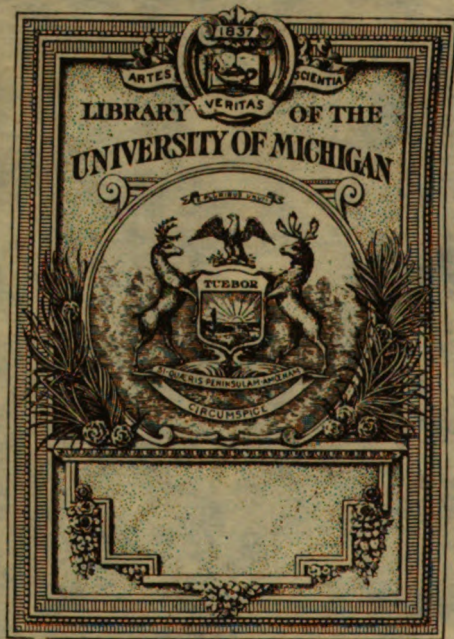
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# *Journal*

Iron and Steel Institute







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1904

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BENNETT H. BROUGH  
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# CONTENTS

## SECTION I.—MINUTES OF PROCEEDINGS.

	PAGE
Annual General Meeting . . . . .	1
Election of Members . . . . .	1
Report of Council . . . . .	9
Annual Statement of Accounts . . . . .	18
Votes of thanks . . . . .	20
Presentation of Bessemer medal . . . . .	22
Andrew Carnegie medal and scholarships . . . . .	25
"Explosions produced by ferro-silicon." By A. Dupré and M. B. Lloyd . . . . .	30
Discussion on Messrs. Dupré and Lloyd's paper . . . . .	35
Correspondence on Messrs. Dupré and Lloyd's paper . . . . .	39
"The manufacture of pig iron from briquettes at Herräng." By H. Louis . . . . .	40
Discussion on Prof. Louis' paper . . . . .	56
Correspondence on Prof. Louis' paper . . . . .	59
"Notes on the production and thermal treatment of steel in large masses." By C. Johns . . . . .	61
Discussion on Mr. Johns' paper . . . . .	75
Correspondence on Mr. Johns' paper . . . . .	87
Report on "pyrometers suitable for metallurgical work" . . . . .	98
Bibliography of pyrometers and pyrometry . . . . .	154
Discussion on pyrometers . . . . .	160
Correspondence on pyrometers . . . . .	179
"The manufacture of coke in the Hüssener oven at the Clarence Ironworks and its value in the blast-furnaces." By C. Lowthian Bell . . . . .	188
Discussion on Mr. Bell's paper . . . . .	202
Correspondence on Mr. Bell's paper . . . . .	219
"The range of solidification and the critical ranges of carbon-iron alloys." By H. C. H. Carpenter and B. F. E. Keeling . . . . .	224
Discussion on Messrs. Carpenter's and Keeling's paper . . . . .	243
Correspondence on Messrs. Carpenter's and Keeling's paper . . . . .	253
Votes of thanks . . . . .	260
"Troostite." By H. C. Boynton . . . . .	262
Correspondence on Mr. Boynton's paper . . . . .	288
"The synthesis of Bessemer steel." By F. J. R. Carulla . . . . .	291
Correspondence on Mr. Carulla's paper . . . . .	306
"The thermal efficiency of the blast-furnace." By W. J. Foster . . . . .	311
Correspondence on Mr. Foster's paper . . . . .	329
"The plastic yielding of iron and steel." By W. Rosenhain . . . . .	335
Correspondence on Mr. Rosenhain's paper . . . . .	372

316903

	PAGE
"The use of steel in American lofty-building construction." By B. H. Thwaite	391
"The relations between the effects of stresses slowly applied and of stresses suddenly applied in the case of iron and steel." By Pierre Breuil (Abstract)	413
"The influence of varying casting temperature on the properties of steel and iron castings." By P. Longmuir	420
Correspondence on Mr. Longmuir's paper	434
The Annual Dinner	437
Obituary	446
Additions to the Library	453

## SECTION II.—NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

IRON ORES	462
I. Occurrence and composition	462
Formation of ore deposits	462
Mineralogical characteristics of iron ore	463
Iron ore in West Cumberland	464
Iron ore in North Staffordshire	464
Iron ore in Austria	464
Iron ore in Bosnia	465
Iron ore in France	465
Iron ore in Germany	465
Iron ore in Luxemburg	467
Iron ore in Norway	467
Iron ore in Russia	467
Iron ore in Finland	468
Iron ore in Spain	468
Iron ore in Sweden	469
Iron ore in Switzerland	472
Iron ore in India	473
Iron ore in Canada	473
Iron ore in New South Wales	474
Iron ore in Victoria	474
Iron ore in Western Australia	474
Iron ore in the United States	474
Iron ore in the Lake Superior district	475
Iron ore in New York	477
Iron ore in North Carolina	478
Iron ore in Pennsylvania	478
Iron ore in Tennessee	479
Iron ore in Washington	479
Iron ore in Wisconsin	480
Iron ore in Wyoming	480
Iron ore in Cuba	481
Iron ore on the Lower Amazon	481
Iron ore in New Caledonia	481
Manganese ore in Austria	481

# CONTENTS.

v

	PAGE
Manganese ore in India . . . . .	482
Manganese ore in the United States . . . . .	482
Manganese ore in Cuba . . . . .	482
Manganese ore in Chili . . . . .	482
Chrome iron ore in India . . . . .	482
Nickel and cobalt ores . . . . .	483
Tungsten ore . . . . .	483
Molybdenite . . . . .	484
Recent researches on meteorites . . . . .	484
II. Iron ore mining . . . . .	486
Search for magnetic ore deposits . . . . .	486
Hand drills in iron ore mines . . . . .	486
Rock drills . . . . .	486
Open-cast working . . . . .	486
Winding plant at the Oliver mine . . . . .	487
Shaft at the Ashland mine . . . . .	487
Iron ore mining in Minnesota . . . . .	488
Iron ore mining in New York . . . . .	488
Fire-damp explosion in an iron mine . . . . .	488
Sanitation at iron mines . . . . .	489
Handling iron ore . . . . .	489
III. Mechanical preparation . . . . .	490
Improvements in ore dressing . . . . .	490
The concentration of iron ores in Sweden . . . . .	490
Magnetic separators . . . . .	492
IV. Metallurgical preparation . . . . .	495
Calcining iron ore . . . . .	495
Briquetting ore . . . . .	495
REFRACTORY MATERIALS . . . . .	496
Fireclay . . . . .	496
Firebricks . . . . .	497
The Schröder kiln . . . . .	497
Graphite . . . . .	498
Bauxite . . . . .	498
Magnesite . . . . .	498
FUEL . . . . .	501
I. Calorific value . . . . .	501
Calorimetry . . . . .	501
Calorific value of coal . . . . .	501
Pyrometry . . . . .	502
II. Coal . . . . .	504
The composition of coal . . . . .	504
The origin of coal . . . . .	505
Coal in England . . . . .	505
Coal in Austria . . . . .	505
Coal in Belgium . . . . .	505
Coal in France . . . . .	506



	PAGE
Coal in Germany . . . . .	507
Coal in Hungary . . . . .	508
Coal in Italy . . . . .	508
Coal in Russia . . . . .	509
Coal in Spain . . . . .	510
Coal in India . . . . .	510
Coal in Canada . . . . .	510
Coal in New South Wales . . . . .	510
Coal in Victoria . . . . .	510
Coal in Western Australia . . . . .	511
Coal in South Africa . . . . .	511
Coal in Asia Minor . . . . .	511
Coal in Bokhara . . . . .	511
Coal in the United States . . . . .	511
Coal in Alaska . . . . .	512
Coal in Colorado . . . . .	512
Coal in Iowa . . . . .	512
Coal in Kansas . . . . .	512
Coal in Montana . . . . .	512
Coal in Virginia . . . . .	513
Coal in Washington . . . . .	513
Coal in Mexico . . . . .	513
Coal in Brazil . . . . .	513
Coal in Argentina . . . . .	513
Coal in Peru . . . . .	513
Coal in Honduras . . . . .	514
Coal in China . . . . .	514
Peat . . . . .	514
Arsenic in coal . . . . .	515
Vanadium in coal . . . . .	515
Coal storage under water . . . . .	515
III. Charcoal . . . . .	515
Charcoal kilns . . . . .	515
IV. Coke . . . . .	516
Beehive coke . . . . .	516
Improvements in quenching cooke . . . . .	516
By-product cooke . . . . .	517
Utilisation of cooke-oven gases . . . . .	519
A modern cooke-oven plant and cooke-compressing machines . . . . .	520
Coking brown coal . . . . .	521
German and Austrian cokes . . . . .	523
V. Liquid fuel . . . . .	524
Origin of petroleum . . . . .	524
Petroleum in Austria . . . . .	524
Petroleum in Germany . . . . .	526
Petroleum in Italy . . . . .	526
Petroleum in Roumania . . . . .	526
Petroleum in Russia . . . . .	526
Petroleum in Spain . . . . .	526

	PAGE
Petroleum in Trinidad . . . . .	526
Petroleum in Albania . . . . .	526
Petroleum near the Bagdad Railway . . . . .	526
Petroleum in Canada . . . . .	527
Petroleum in India . . . . .	527
Petroleum in the United States . . . . .	527
Petroleum in California . . . . .	528
Petroleum in Colorado . . . . .	528
Petroleum in Idaho . . . . .	528
Petroleum in Kansas . . . . .	529
Petroleum in Missouri . . . . .	529
Petroleum in Texas-Louisiana . . . . .	529
Petroleum in Peru . . . . .	530
Oil shale . . . . .	530
Asphalt . . . . .	530
Boring for petroleum . . . . .	533
Oil fuel burners . . . . .	533
The use of liquid fuel . . . . .	533
<b>VI. Natural gas . . . . .</b>	<b>533</b>
Natural gas in South Germany . . . . .	533
Natural gas in Austria . . . . .	534
Natural gas in Kansas . . . . .	534
<b>VII. Artificial gas . . . . .</b>	<b>534</b>
Thermal reactions in the gas producer . . . . .	534
Gas producers . . . . .	534
Water gas . . . . .	536
Mond gas . . . . .	537
Gas-power plant . . . . .	537
Brown coal producer gas . . . . .	538
<b>VIII. Coal mining . . . . .</b>	<b>538</b>
Deep boring . . . . .	538
Underground temperatures . . . . .	538
Shaft sinking . . . . .	539
Winding appliances . . . . .	540
Winding ropes . . . . .	544
Underground haulage . . . . .	544
Mine supports . . . . .	545
Electricity in mines . . . . .	545
Compressed air in mines . . . . .	547
Explosives and blasting . . . . .	547
Coal cutting . . . . .	548
Methods of working . . . . .	549
Mine drainage . . . . .	551
The ventilation of collieries . . . . .	553
Fire-damp explosions . . . . .	553
Coal-dust explosions . . . . .	554
The lighting of collieries . . . . .	554
Underground fires . . . . .	554
History of coal mining . . . . .	555

	PAGE
Mine surveying . . . . .	555
Sanitation in collieries . . . . .	556
<b>IX. Coal washing and screening . . . . .</b>	<b>557</b>
Separating slate from coal . . . . .	557
Coal screening . . . . .	557
Washing coal . . . . .	558
Handling coal . . . . .	558
Firing with coal dust . . . . .	559
Briquettes . . . . .	560
<b>PRODUCTION OF PIG IRON . . . . .</b>	<b>562</b>
<b>I. Blast-furnace practice . . . . .</b>	<b>562</b>
Construction of modern blast-furnaces . . . . .	562
Stock distribution in the blast-furnace . . . . .	562
Flue dirt and top pressure in blast-furnaces . . . . .	563
Health area and tuyeres . . . . .	563
Failure of a blast-furnace lining . . . . .	564
Charcoal blast-furnaces . . . . .	564
The Staph continuous blast-furnace . . . . .	565
Blast-furnace fuel . . . . .	566
Pump for ironworks . . . . .	568
Blowing engines . . . . .	568
Motive-power from blast-furnace gas . . . . .	568
English blast-furnace practice . . . . .	571
Canadian blast-furnaces . . . . .	571
The Elba blast-furnaces . . . . .	571
Spanish blast-furnace . . . . .	571
Swedish blast-furnaces . . . . .	572
American blast-furnace practice . . . . .	573
History of iron . . . . .	578
<b>II. Chemical composition of pig iron . . . . .</b>	<b>580</b>
Pig iron classes . . . . .	580
"Glazed" pig iron . . . . .	580
Gases in pig iron . . . . .	581
The calculation of blast-furnace burdens . . . . .	583
Zinc in the blast-furnace . . . . .	584
<b>III. Blast-furnace slags . . . . .</b>	<b>585</b>
Utilisation of slags . . . . .	585
Portland cement from blast-furnace slag . . . . .	587
Ancient slags . . . . .	588
<b>IV. Foundry practice . . . . .</b>	<b>588</b>
Cupola practice . . . . .	588
Defects in cast iron . . . . .	589
Loss of iron in the cupola . . . . .	589
Cleaning cupola gases . . . . .	589
Fore-hearths to cupolae . . . . .	590
The crucible furnace in foundry practice . . . . .	592
Loss of iron in the reverberatory furnace . . . . .	593

	PAGE
Manganese ore in the cupola . . . . .	594
Limestone in the cupola . . . . .	594
Carborundum in the cupola . . . . .	594
Fluorspar in the cupola . . . . .	595
Acid-proof castings . . . . .	595
Cleaning castings with weak acid . . . . .	595
A large casting . . . . .	596
Explosion in a foundry . . . . .	596
Foundry appliances . . . . .	596
Moulding . . . . .	598
Malleable castings . . . . .	599
<b>PRODUCTION OF MALLEABLE IRON . . . . .</b>	<b>602</b>
Puddling . . . . .	602
The fusion of malleable iron . . . . .	602
Native iron smelting . . . . .	602
Electric smelting of iron ore . . . . .	603
Electric production of iron alloys . . . . .	605
<b>FORGE AND MILL MACHINERY . . . . .</b>	<b>607</b>
Steel forgings . . . . .	607
Design of rolls . . . . .	607
Comparison of small and large mill plant . . . . .	609
Roller-driven tables . . . . .	609
Continental rolling mill plant . . . . .	609
American rolling mill plant . . . . .	610
Gas driven rolling mills . . . . .	612
Electric power in the rolling mills . . . . .	613
Rolling mill engines . . . . .	614
Generation and distribution of power . . . . .	614
Tube rolling . . . . .	615
<b>PRODUCTION OF STEEL . . . . .</b>	<b>617</b>
<b>I. The carburisation of malleable iron . . . . .</b>	<b>617</b>
The manufacture of crucible steel . . . . .	617
Thermal balance of a crucible steel furnace . . . . .	618
<b>II. The open-hearth process . . . . .</b>	<b>618</b>
Open-hearth furnace design . . . . .	618
Steel production without scrap or ore . . . . .	619
Gas losses in the open-hearth furnace . . . . .	620
Additions in the open-hearth process . . . . .	621
Gas and tar as fuel . . . . .	622
Basic open-hearth steel . . . . .	623
Continuous practice in a fixed hearth . . . . .	624
Handling pit scrap . . . . .	625
Small open-hearths for castings . . . . .	626
Charging machines . . . . .	626
New French steelworks . . . . .	627
Russian steelworks . . . . .	628
American open-hearth steel plants . . . . .	629

	PAGE
<b>III. The Bessemer process</b>	630
Small converters	630
Converter accessories	635
American Bessemer plant	635
Basic Bessemer slag	636
Mixed Bessemer and open-hearth process	637
<b>FURTHER TREATMENT OF IRON AND STEEL</b>	638
Production of sound ingots	638
Gas welding and heating furnaces	639
Cold working of steel	640
Doors for heating pits	641
Steel castings	641
Preventing blow-holes in ingots and castings	641
Use of thermite for castings	641
Electric welding	642
High speed tool steels	642
The manufacture of eye-bars	644
Rails	644
Chilled wheels	645
Steel waggons	645
Structural ironwork	645
Construction of cranes in Germany	645
Manufacture of projectiles	646
Manufacture of tin-plates	646
<b>PHYSICAL PROPERTIES</b>	647
Crystallisation of iron	647
Surface structure of solids	647
The semi-fluid state of metals	647
The elastic limit	648
Metallography	649
Magnetic properties of iron	651
Segregation in steel	652
Determination of critical points	652
Heat treatment of steel	653
The effect of repeated heating on iron and steel	654
Hardening of steel	655
Brittleness of steel	655
Special iron alloys	655
Manganese steel	657
Nickel steel	659
Silicon steel	659
Vanadium steel	659
Faulty boiler plates	660
Testing machines	662
The effect of alternate stresses	662
Tensile and repeated stresses	662
The physics of cast iron	663
Testing cast iron	664

	PAGE
Strength and structure of cast iron . . . . .	666
Tests of metals . . . . .	668
Variations in structure and tests of steel . . . . .	668
Tensile tests of mild steel . . . . .	669
Strength of steel castings as affected by temperature . . . . .	671
Strength of circular steel plates . . . . .	672
Standard specifications . . . . .	672
Specifications for cast iron . . . . .	672
Steel specifications . . . . .	672
Rails . . . . .	673
Wrought iron and cast iron pipes . . . . .	673
Armour tests . . . . .	674
<b>CHEMICAL PROPERTIES . . . . .</b>	<b>675</b>
Atomic weight of iron . . . . .	675
Oxygen and sulphur in cast iron . . . . .	675
Red-shortness . . . . .	675
Corrosion of iron and steel . . . . .	676
Ferro-manganese slag . . . . .	678
<b>CHEMICAL ANALYSIS . . . . .</b>	<b>680</b>
<b>I. Analysis of iron and steel . . . . .</b>	<b>680</b>
Ironworks analysis . . . . .	680
Determination of carbon . . . . .	681
Determination of silicon . . . . .	681
Determination of manganese . . . . .	682
Determination of sulphur . . . . .	683
Determination of tungsten . . . . .	684
Determination of vanadium . . . . .	684
Determination of titanium . . . . .	686
<b>II. Analysis of iron ores and slag . . . . .</b>	<b>687</b>
Analysis of minette . . . . .	687
Determination of iron . . . . .	688
Analysis of basic slag . . . . .	689
<b>III. Fuel analysis . . . . .</b>	<b>689</b>
Determination of sulphur . . . . .	689
Coal ash . . . . .	690
Coal analysis . . . . .	690
<b>IV. Gas analysis . . . . .</b>	<b>690</b>
Fractional combustion . . . . .	690
<b>STATISTICS . . . . .</b>	<b>691</b>
<b>I. United Kingdom . . . . .</b>	<b>691</b>
Mineral statistics . . . . .	691
Iron trade statistics . . . . .	691
Imports and exports . . . . .	692
Accidents in mines and quarries . . . . .	692
Iron ore . . . . .	692
Open-hearth furnaces . . . . .	692
Coal . . . . .	693
Iron and steel industries . . . . .	693

	PAGE
II. Australasia . . . . .	694
Mineral statistics of Queensland . . . . .	694
III. Austria-Hungary . . . . .	694
Mineral statistics . . . . .	694
Brown coal in Bohemia . . . . .	695
Coal mining in Hungary . . . . .	696
Mineral statistics of Bosnia and Herzegovina . . . . .	696
IV. Belgium . . . . .	696
Mineral statistics . . . . .	696
Steelworks . . . . .	697
V. Canada . . . . .	697
Mineral statistics . . . . .	697
The mining industry of Newfoundland . . . . .	698
VI. China . . . . .	698
The mineral resources of Indo-China . . . . .	698
Iron foundries in Tonkin . . . . .	699
Coal at Kiao-chou . . . . .	699
VII. France . . . . .	699
Iron trade statistics . . . . .	699
Coal . . . . .	700
VIII. Germany . . . . .	700
Mineral statistics . . . . .	700
Iron trade statistics . . . . .	701
Mineral statistics of Luxemburg . . . . .	703
Mineral statistics of Alsace-Lorraine . . . . .	703
Canal transport . . . . .	703
Metallurgical education . . . . .	703
IX. Holland . . . . .	704
Coal . . . . .	704
X. India . . . . .	705
Mineral statistics . . . . .	705
Mineral statistics of Mysore . . . . .	706
XI. Japan . . . . .	706
Mineral statistics . . . . .	706
XII. Mexico . . . . .	706
Mineral industry . . . . .	706
XIII. Norway . . . . .	707
Mineral statistics . . . . .	707
XIV. Portugal . . . . .	707
Mineral statistics . . . . .	707
XV. Roumania . . . . .	707
Petroleum . . . . .	707

# CONTENTS.

xiii

	PAGE
<b>XVI. Russia</b> . . . . .	708
Iron trade statistics . . . . .	708
Petroleum . . . . .	712
<b>XVII. South America</b> . . . . .	712
Mineral resources . . . . .	712
<b>XVIII. Spain</b> . . . . .	713
Mineral statistics . . . . .	713
<b>XIX. Sweden</b> . . . . .	714
Iron trade statistics . . . . .	714
<b>XX. United States</b> . . . . .	715
Iron trade statistics . . . . .	715
Mineral statistics . . . . .	717
Production of iron ores . . . . .	717
Production of manganese ore . . . . .	718
Steel hardening metals . . . . .	718
Natural gas . . . . .	719
Accidents in collieries . . . . .	719
<b>XXI. Comparative tables</b> . . . . .	720
The world's production of coal and iron . . . . .	720
The world's production of steel . . . . .	722
The world's production of ammonium sulphate . . . . .	722
Miners' wages . . . . .	723
<b>BIBLIOGRAPHY</b> . . . . .	724
Metallurgy . . . . .	724
Mining . . . . .	728
<b>INDEX</b> . . . . .	733

## LIST OF PLATES.

	PAGE
<b>I. to IX. Drawings illustrating Professor Louis' paper</b> . . . . .	56
<b>X. to XII. Drawings and Photomicrographs illustrating Mr. Johns' paper</b> . . . . .	74
<b>XIII. to XVII. Drawings illustrating Mr. Bell's paper</b> . . . . .	200
<b>XVIII. to XXVI. Drawing, Photographs, and Photomicrographs illustrating Messrs. Carpenter and Keeling's paper</b> . . . . .	242





# THE IRON AND STEEL INSTITUTE.

## SECTION I. *MINUTES OF PROCEEDINGS.*

### ANNUAL GENERAL MEETING.

THE ANNUAL GENERAL MEETING of the IRON AND STEEL INSTITUTE was held at the Institution of Civil Engineers, Great George Street, London, on Thursday, 5th May 1904 — Mr. ANDREW CARNEGIE, LL.D., President, in the Chair.

The SECRETARY read the Minutes of the last meeting, held at Barrow-in-Furness on 1st, 2nd, and 3rd September 1903, which were confirmed and signed.

Mr. WALTER DIXON and Mr. J. W. WAINWRIGHT were appointed Scrutineers, and on the completion of the scrutiny reported that the following gentlemen had been duly elected as Members of the Institute :—

NAME.	ADDRESS.	PROPOSERS.
Adams, Edwin . . .	Ordsal Works, Salford, Manchester	John D. Ellis, Walter M. Musgrave, J. Rossiter Hoyle.
Allen, Cecil . . . .	Henry Bessemer & Co., Ltd., Sheffield	Fred Mills, John D. Ellis, J. H. Wicksteed.
Allott, Matthew Henry	Green Bank, Gerard Road, Rotherham	Henry Steel, jun., William Tozer, William Steel.
Anderson, James . .	New Russia Company, 4 Moorgate Street, London, E.C.	John J. Hughes, Arthur D. Hughes, William Whit- well.

NAME.	ADDRESS.	PROPOSERS.
Arnold, Sir Alfred . .	Messrs. James Royston, Son & Co., Ltd., Halifax	J. E. Stead, W. H. Bleckly, William Whitwell.
Bacci, Carlo . . . .	7 Via Bufalini, Florence, Italy	Isaac Butler, William Evans, W. Bright.
Bagley, Chas. Henry F.	Hartburn, Stockton-on-Tees	Tom Westgarth, Arthur Cooper, Benjamin Talbot.
Bagnall-Wild, <i>Lieut.</i> Ralph Kirkby, R.E.	War Office, Horse Guards, Whitehall, London, S.W.	Lt.-Col. J. H. Cowan, Otto Gossell, J. E. Stead.
Bates, Herbert . . .	Jesmond Dene, Eccles Old Road, Pendleton, Manchester	David Evans, Walter M. Musgrave, Edward Wood.
Bedford, William James	Lion Works, Mowbray Street, Sheffield	J. Longbotham, R. H. Longbotham, Arthur Horsfield.
Berg, P. Torsten . .	Grand Hotel, Stockholm, Sweden	Andrew Carnegie, J. A. Brinell, Axel Wahlberg.
Best, Frederick . . .	"Ringstead," Dore, near Sheffield	Lewis J. Firth, J. Rossiter Hoyle, John D. Ellis.
Blyde, J. E. Alger . .	The Wallace Steel Works, Sheffield	J. O. Arnold, Albert Senior, W. H. Walker.
Booth, Philip Lancashire	1 Hartington Street, Barrow-in-Furness	G. W. Wilkinson, T. E. G. Marley, George Scoular.
Bowman, Harold Edelsten	Canal Foundry, Preston	E. J. Duff, Henry Cooper, J. R. Ross.
Brightmore, Frederick	Hall Cross Villa, Doncaster	Arthur Horsfield, Leason Gray, F. H. Wigham.
Bunch, Charles Edward	Bridge House, Warrington	W. H. Bleckly, J. J. Bleckly, W. Peter Rylands.
Burnyeat, Richard Whiteside	Mossbay Hæmatite Iron and Steel Co., Ltd., Workington	William Burnyeat, R. E. Highton, F. Beattie.
Burt, William Henry	Rosemore, Middlesbrough	J. M. While, W. H. Moore-Bowman, A. M. Butchart.
Carlsson, Hugo . . .	Dominion Iron and Steel Company, Sydney, C.B., Canada	C. Lowthian Bell, E. H. Saniter, Greville T. Jones.
Carpenter, Henry Cort Harold, M.A., Ph.D.	The National Physical Laboratory, Teddington	R. A. Hadfield, P. B. Brown, I. B. Milne.
Carr, William M. . .	American Steel Foundries, E. St. Louis, Illinois, U.S.A.	R. A. Hadfield, A. G. M. Jack, I. B. Milne.
Chatwood, Arthur Brunel, B.Sc., Assoc. M. Inst. C.E., M. I. Mech.E.	12 Exchange Street, Manchester	Samuel Chatwood, R. Price-Williams, Henry Webb.
Clamens, Jean Baptiste	21 Rue de Godot de Mauroi, Paris	William Whitwell, A. Pourcel, F. Osmond.
Clark, Eugene B. . .	5335 Cornell Avenue, Chicago, Illinois, U.S.A.	T. W. Robinson, S. T. Wellman, G. R. Johnson.
Clements, Olaf P. . .	Birmingham Small Arms Co., Ltd., Small Heath, Birmingham	Henry A. Wiggin, William H. Greenwood, A. E. Tucker.

NAME.	ADDRESS.	PROPOSERS.
Clough, Thomas Carter	Carbrook Steel Works, Sheffield	Henry Cooper, Cosmo Johns, J. H. S. Dickenson.
Coppée, Evence, jun. .	211 Avenue Louise, Brussels	E. Windsor Richards, Arthur Keen, Sir Edward H. Carbutt.
Cowan, John. . . .	Clydebridge Steel Works, Cambuslang, N.B.	Edgar J. W. Richards, J. E. Stead, W. Clark.
Davenport, John Edward	The Elms, Oulton, near Leeds	Arthur Horsfield, Leason Gray, T. B. Loxley.
Davie, William Symington	Waverley Iron and Steel Co., Ltd., Coatbridge, N.B.	George Garrett, Thomas Davie, J. S. Trinham.
Defays, Victor . . .	29 Rue de Monastère, Brussels	H. Ponthière, Evence Coppée, A. V. Passelecq.
Dickson, James. . .	Waverley Works, Sheffield	Sydney J. Robinson, William Tozer, T. Jobson,
Donaldson, William Anderson	7 Royal Bank Place, Glasgow	Neil Robson, T. B. Rogers, J. M. While.
Downe, Henry Smith	90 Shoe Lane, London, E.C.	Sydney J. Robinson, William Tozer, J. Stanley Watson.
Driver, Augustus Henry Murray	Birmingham Small Arms Co., Ltd., Small Heath, Birmingham	Henry A. Wigg, William H. Greenwood, A. E. Tucker.
Dumas, Louis Charles	24 Rue de Turin, Paris	R. A. Hadfield, P. B. Brown, I. B. Milne.
Earp, Henry Proctor .	32 Southfield Road, Middlesbrough	C. Lowthian Bell, Greville T. Jones, E. H. Saniter.
Ellison, William Reynolds	406 Firth Park Road, Sheffield	J. O. Arnold, A. McWilliam, E. F. Lange.
Engel, Bergmeister Konrad	Friedrichstrasse 2, Essen a/d Ruhr, Germany	C. Lueg, E. Schrödter, R. M. Daelen.
Evans, Henry Morton Glyn	Llangennech Park, Carmarthenshire	Hubert S. Thomas, J. F. Melling, W. G. Kirkaldy.
Evans, Thomas Granger	Thornlea, Millhouses, Sheffield	B. M. Renton, Herbert Barber, C. W. Hawkaley.
Everitt, Charles Kingston	Imperial Steel Works, Sheffield	W. E. Allen, J. E. Stead, Fred Seaman.
Fitzgerald, John Morton	Crane Iron Works, Catasauqua, Pa., U.S.A.	Leonard Peckitt, Richard Peters, William Whitwell.
Flather, Gerald Darwin	Standard Steel Works, Sheffield	Robert Schott, Alfred H. Allen, G. Senior.
Ford, James . . . .	Farnworth, Bolton, Lancashire	J. F. Melling, Joseph Gregory, G. G. S. Grundy.
Fryer, Tom Jefferson.	20 Change Alley, Sheffield	Thos. Wilkinson, Ambrose Firth, G. J. Mair.
Galloway, William Johnson, M.P.	36 Portman Square, London, W.	Alfred Baldwin, James Heath, Sir Thomas Wrightson.
Graham, Maurice, M.I.Mech.E.	Summerhill, Apperley Bridge, Yorkshire	J. R. Ross, George Ritchie, T. H. Lauder.
Harry, David . . . .	Forest Villa, near Llanelli	Ernest Trubshaw, Daniel Williams, W. A. Davy.

NAME.	ADDRESS.	PROPOSERS.
Hill, Joseph . . . .	St. George's Engineering Works, Derby	George Hatton, W. Hutchinson, J. H. Darby.
Holland, Job . . . .	3 Kenwood Bank, Sharrow, Sheffield	J. E. Stead, J. J. Pickford, Arthur W. Richards.
Hughes, Herbert . . .	Onslow House, Sheffield	T. E. Vickers, A. J. Hobson, Sydney J. Robinson.
Hulme, James . . . .	Ashleigh, Harefield, Middlesex	G. J. Snelus, Hugh Bell, Professor Thomas Turner.
Hunter, John . . . .	Jeasmond, Chester Road, Queensferry, Flint	Mark Robinson, A. Tannett-Walker, William Whitwell.
Hutin, Edmond . . . .	Villerupte (Meurthe-et-Moselle), France	C. Lowthian Bell, Greville Jones, W. L. Johnson.
Jackson, Ernest Wilfrid	11 Queen's Terrace, Middlesbrough	Illyd Williams, Arthur Cooper, J. E. Stead.
Johnson, Elias M. . .	Sputyen Duyvil, New York	James Douglas, C. Kirchhoff, G. W. Maynard.
Kearns, Henry Ward, B.Sc.	Baxenden House, Accrington	Robert Whitehead, Charles Markham, A. W. Galloway.
Keeling, Bertram F. E., B.A.	National Physical Laboratory, Teddington	R. A. Hadfield, P. B. Brown, I. B. Milne.
Kennard, R. W. . . .	Llwyn - Dau Court, Abergavenny	E. P. Martin, E. Windsor Richards, A. Tannett-Walker.
Kirk, Thomas, jun. . .	Carlton Iron Works, via Ferry Hill, co. Durham	Arthur Cooper, J. E. Stead, W. Thomlinson.
Lacanne, Félix . . . .	Société la Providence, Marchienne au Pont, Belgium	V. Latinis, A. Greiner, E. Lelong.
Lambert, Thomas . . .	Napier Forge & Hammer Works, Sheffield	Albert Senior, Thomas Davage, T. W. Willis.
Laqvist, Orvar . . . .	Stortorget 1, Stockholm	Axel Wahlberg, Carl Ångström, Gunnar Dillner.
Larke, William James	59 Hillmorton Road, Rugby	H. J. Cornish, James T. Milton, A. B. W. Kennedy.
Laverick, John H. W.	Messrs. James Oakes & Co., Ridding, Alfreton	Maurice Deacon, G. R. Oakes, Herbert Pilkington.
Lavino, E. J. . . . .	Bullitt Building, Philadelphia, U.S.A.	E. Clavay Chalas, F. Dupré, J. Stuart Horner.
Le Chatelier, <i>Professor</i> Henry Louis	75 Rue Notre Dame des Champs, Paris	Andrew Carnegie, F. Osmond, Sir Lowthian Bell.
Lees, John . . . . .	Oaklands, Handsworth	Sir B. Hingley, Ebenezer Parkes, E. C. Keay.
Longden, Alfred Henry	Stanton-by-Dale, Nottingham	J. A. Longden, G. J. Ward, James Proctor.
McFarlane, William . .	Barrakar Iron Works, Bengal, India	David Evans, A. Tannett-Walker, J. Angus.
Mackay, Harry J. Sutherland	53 Deansgate Arcade, Manchester	E. G. Constantine, C. G. Norris, J. H. Harrison.
Marshall, Charles Cecil	46 Guildhall Road, Northampton	Sir B. Hingley, E. P. Davis, Henry A. Webb.
Martin, Hugh . . . .	Coatbridge Iron Works, Coatbridge	F. Finlayson, John Tennent, James Kerr.

NAME	ADDRESS	PROPOSERS
Martin, John . .	58 West Regent Street, Glasgow	Edgar J. W. Richards, J. E. Stead, W. Clark.
Mathews, John Alex- ander, D.Sc.	Crucible Steel Com- pany of America, Syracuse, New York, U.S.A.	Andrew Carnegie, W. Gow- land, H. M. Howe.
Mechan, Arthur. . .	Scotstoun Iron Works, Glasgow	James Bennie, William Jacks, Dugald Rennie, jr.
Melhuish, Richard . .	84, 85, and 87 Fetter Lane, London, E.C.	G. Senior, Albert Senior, G. E. Hoyland.
Merrett, Wm. Henry, Assoc.R.S.M.	Hatherley, Grosvenor Road, Wallington, Surrey	W. Gowland, A. Campion, J. E. Stead.
Moorwood, Hedley Stanley	Harlestone Iron Works, Sheffield	J. Rossiter Hoyle, T. W. Ward, F. Colin Moorwood.
Morgan, John . . .	321 East 11th Street, Portsmouth, Ohio, U.S.A.	Arthur Cooper, Arthur W. Richards, J. E. Stead.
Moses, Moses . . .	122 Splott Road, Car- diff	E. Windsor Richards, E. P. Martin, William Evans.
Mott, Samuel Thornley	The English McKenna Process Co., Ltd., Dock Road, Birken- head	Mark Robinson, J. T. Mid- dleton, J. H. Wicksteed.
Mount-Haes, A., M.I.Mech.E.	Erfstrasse 19, Cologne, Germany	J. Becker, L. W. Breuer, R. M. Daelen.
Müller, Franz J. . .	Stahlstrasse 54, Mei- derich, bei Ruhrort	E. Schrödter, R. M. Daelen, H. Lueg.
Müller, Gustav . . .	Rheinische Metall- waaren und Maschin- enfabrik, Düsseldorf, Germany	R. M. Daelen, E. Schrödter, A. Custodis.
Muras, Robert . . .	Normanhurst, New- bridge, Wolverhampton	H. Le Neve Foster, E. D. Nicholson, A. E. Tucker.
Nelson, Andrews Sclanders	Messrs. Hurst, Nelson & Co., Ltd., Mother- well, N.B.	Robert Russell, Henry Bumby, T. McLeod Percy.
Noake, Frank . . .	Weston, Avondale Road, Wolverhampton	Sir A. Seale Haslam, G. H. Cloughton, T. B. Adams.
Osborn, Frederick Marmaduke	Clyde Steel and Iron Works, Sheffield	A. Stanley Pye-Smith, Arnold Pye-Smith, Samuel Osborn.
Outhwaite, Harry . .	The Laurels, Linthorpe, Middlesbrough	Arthur W. Richards, J. E. Stead, J. H. Moysey.
Peacock, Tom Swift .	New Mills House, Walsall	Edward Richards, Lincoln Chandler, A. E. Horton.
Pearson, William Henry	6 Fenchurch Buildings, London, E.C.	David Evans, B. Willans, J. E. Stead.
Pehrson, Alfred Petter	22 High Street, Shef- field	Axel Sahlin, C. Dellwik, J. O. E. Trotz.
Pettit, Walter Richard	Ferry Works, Queens- ferry, Flint	Mark Robinson, A. Tannett- Walker, William Whit- well.
Piccioli, Arturo . . .	Portovecchio, Tuscany, Italy	Isaac Butler, William Evans, W. Bright.

NAME	ADDRESS.	PROPOSERS.
Redding, Richard James	Royal Laboratory Department, Woolwich Arsenal	R. A. Hadfield, A. G. M. Jack, J. M. Ledingham.
Rees, William David.	Metropolitan Bank Chambers, Wind Street, Swansea	Herbert Eccles, F. B. Last, H. Robinson.
Rees, William John .	Uplands, near Llanely, Carmarthen	Hubert S. Thomas, C. W. James, J. F. Melling.
Reusch, Paul. . . .	Mulheim a. d. Ruhr, Germany	E. Schrödter, R. M. Daelen, F. Wüst.
Rhodes, Charles F. .	St. John's, Wakefield	R. H. Longbotham, William Firth, Arthur Horsfield.
Richards, Joseph William, Ph.D.	Lehigh University, Bethlehem, Pa., U.S.A.	H. M. Howe, John Fritz, Ambrose Monell.
Richards, William . .	Phoenix Iron Works, Leicester	Jos. Jackman, A. J. Jackman, Albert Senior.
Ruhl, Louis . . . .	100 William Street, New York	August Wiener, J. O. Arnold, W. G. Kirkaldy.
Sauveur, Albert . .	446 Tremont Street, Boston, Mass., U.S.A.	A. Ladd Colby, Maunsell White, H. M. Howe.
Senior, George Edward	Ellerslie, Dore, Sheffield	Robert Colver, Percy W. Lee, J. B. Tompkin.
Sevieri, Vieri, Ph.D. .	Piombino, Italy	C. Ritter von Schwarz, Baron H. von Jüptner, William Whitwell.
Shedden, Duncan Jones	Winterbourne, Dudley, Worcester	Sir Benjamin Hingley, G. H. Cloughton, H. W. Hughes.
Smith, Enos . . . .	Pyenot Hall, Cleckheaton	Thos. Wilkinson, R. Heber Radford, H. E. Hodgson.
Stanger, Reginald H. Harry	Testing Works and Laboratories, 2 Broadway, Westminster, London, S.W.	Vaughan Pendred, Berkeley Paget, A. C. Hurtzig.
Stevens, Samuel Edward	Prospect House, Hexthorpe, Doncaster	T. Wilkinson, A. Horsfield, R. Heber Radford.
Stevenson, George . .	Manor House, Eckington, near Sheffield	T. Wilkinson, J. H. Barber, A. Firth.
Stockton, Joseph Sadler, M.I.Mech.E.	Carbrook Steel Works, Sheffield	Henry Cooper, Cosmo Johns, J. H. S. Dickenson.
Storey, Charles B. C., M.A.	Lancaster	J. T. Smith, T. F. Butler, W. J. P. Storey.
Strain, Hugh, jun. .	Crosshill Cottage, Motherwell, N.B.	John Strain, James Kerr, Andrew Lamberton.
Sundgren, E. A. . .	Kamenskoie, Russia	R. A. Hadfield, J. Stanley Watson, G. G. Coppel.
Surzycki, Stanislas .	Société B. Hantke, Czenstochowa, Poland	B. Talbot, W. Deighton, T. Twynam.
Symington, Hugh . .	Stewarton, Coatbridge, N.B.	George Garrett, Thomas Davie, J. S. Trinham.
Symington, Thomas .	Stewarton, Coatbridge, N.B.	George Garrett, Thomas Davie, J. S. Trinham.
Tata, Dorabjee Jamsitjee	Victoria Buildings, Fort, Bombay	Jamsitjee N. Tata, William Whitwell, Andrew Carnegie.

NAME.	ADDRESS.	PROPOSERS.
Tatham, Thomas Leonard Thomas, Alexander Shirreff	Whitworth Street West, Manchester 9 Fitzalan Place, Cardiff	W. H. Davies, Isaac Butler, Henry Webb. E. Windsor Richards, E. P. Martin, William Evans.
Timmermans, François	28 Quai de Fragnée, Liège	V. Latinis, H. Ponthière, E. Lelong.
Trube, Gustave Adolph	Westinghouse Works, Trafford Park, Man- chester	W. P. Ingham, W. S. Doran, W. H. Panton.
Varley, Reginald Wells	2 Hyde Park Terrace, Leeds	F. J. Kitson, Ralph G. Scott, W. Deighton.
Verity, Joseph . . .	Railway Wheel Works, Mexbrough, Yorks.	Arthur Horsfield, Leason Gray, F. J. T. Wheeler.
Waterston, Hugh Crawford	Kenmure, Coatbridge, N.B.	George Garrett, Thomas Davie, J. S. Trinham.
Waterston, Robert .	Kenmure, Coatbridge, N.B.	George Garrett, Thomas Davie, J. S. Trinham.
Weeks, Henry Bridges, F.I.C.	The Retreat, Infield Park, Barrow-in-Fur- ness	J. M. While, Thomas Danks, W. H. Moore-Bowman.
Weiskopf, Alois, D.Ing.	Sophienstrasse 3, Han- over, Germany	H. Wedding, F. W. Lür- mann, Andrew Carnegie.
West, George Frederick	York Mansion, West- minster, London, S.W.	W. H. Butlin, James Roberts, George Cawley.
Wheeler, Percy M.I.Mech.E. . . .	Broadwell Road, Old- bury, near Birming- ham	T. B. Hall, Arthur Keen, Sir T. Salter Pyne.
Whitehouse, Benjamin	Wood Bank, Sedgely, near Dudley	E. D. Nicholson, H. Le Neve Foster, A. E. Tucker.
Whitfield, Charles . .	Victoria Works, Ketter- ing	A. Tannett-Walker, C. G. Norris, W. H. Fowler.
Widdowson, John Henry	25 Withington Road, Whalley Range, Man- chester	Thos. Ashbury, Henry Webb, Charles Scott.
Wilcox, Charles . .	Ravensthorpe, Lord's Wood Road, Har- borne	James Patchett, Walter Jenks, Ernest Farnworth.
Wild, Frank Dickin- son	Borussia Steel Works, Sheffield	R. A. Hadfield, A. G. M. Jack, I. B. Milne.
Wilkins, William . .	National Tube Co., Wheeling, West Vir- ginia, U.S.A.	J. F. L. Crosland, W. H. Bradley, Frank C. Roberts.
Willard, Eugene B., jun.	Wellston, Ohio, U.S.A.	J. H. Cremer, S. T. Well- man, Julian Kennedy.
Williams, David . .	232 William Street, New York, U.S.A.	Andrew Carnegie, Frank C. Roberts, C. Kirch- hoff.
Wincott, George P. .	Abbey Road, Barrow- in-Furness	G. S. Packer, R. E. Highton, Thomas Carlisle.
Woodman, Francis John	Chapel House, Chapel Street, St. George's, Wellington, Salop	Anthony Patterson, Albert Tilley, James Thomas.
Woodward, Robert Guthrie	Oakholme, Workop	R. Heber Radford, W. Edgar Allen, R. Woodward.



NAME.	ADDRESS.	PROPOSERS.
Wuester, Gustav . .	Moscow, Russia	Sydney J. Robinson, J. Stanley Watson, G. G. Coppel.
Yakovleff, Vladimir .	Oboukhovo Steel Works, St. Petersburg, Russia	Andrew Carnegie, R. A. Hadfield, William Whit- well.
Zethelius, Ludwig . .	Falun, Sweden	E. J. Ljungberg, A. G. Ljungberg, Lars Yng- ström.

The SECRETARY then read the following Report of the Council upon the proceedings of the Institute during the year 1903 :—

## REPORT OF COUNCIL.

At this the thirty-fifth Annual General Meeting of the Iron and Steel Institute, the Council present to the members their Report on the proceedings of the Institute during the year 1903, and are glad to note that during the year the Institute has made very satisfactory progress.

## THE ROLL OF THE INSTITUTE.

During the year 1903 there have been added to the register one hundred and sixty-one names. The number of members on the roll of the Institute on December 31st, 1903, was:—

Patron . . . . .	1
Honorary Members . . . . .	9
Life Members . . . . .	27
Ordinary Members . . . . .	1744
Total . . . . .	<u>1781</u>

The growth of the Institute during the past thirty years is shown by the following statistics:—

	1873	1883	1893	1903
Patron . . . . .	...	...	...	1
Hon. Members . . . . .	7	5	5	9
Life Members . . . . .	...	...	...	27
Ordinary Members . . . . .	644	1127	1438	1744
Totals . . . . .	651	1132	1443	1781

The Council have to congratulate several members of the Institute who have had high distinctions conferred upon them. Sir W. T. Lewis, Bart., Vice-President, has been appointed a member of the Royal Commission on Trade Disputes and Trade Combinations; Mr. Victor Cavendish, M.P., Member of Council, has been appointed Financial Secretary to the Treasury; Sir Alfred Hickman, M.P., has had conferred upon him the dignity of a Baronetcy; and Mr. Stead, Member of Council, has been elected a Fellow of the Royal Society, and has been appointed the representative of Great Britain on the Council of the International Testing Association. Mr. Gustave Canet, Honorary Member, has had conferred upon him the Grand Cross of the Norwegian Order of St. Olaf. Mr. A. de Montgolfier, Honorary Member, has been

created a Knight Commander of the Order of St. Ann of Russia ; and Professor H. Wedding, Honorary Member, has been created a Knight Commander of the Prussian Order of the Crown. Among the honours that have been bestowed upon members of the Institute, the Council note that Sir John Aird has received the Grand Cordon of the Imperial Ottoman Order of the Medjidieh ; Mr. W. F. Beardshaw has been re-elected President of the Sheffield Chamber of Commerce ; Mr. E. Coppée has been created a Knight of the Order of Leopold ; Professor J. A. Ewing has been elected an Honorary Fellow of King's College, Cambridge, and has been appointed a member of the Explosives Committee in succession to the late Sir W. Roberts-Austen ; Mr. M. Géný (Le Creusot) has been created a Knight of the Order of St. Stanislas of Russia ; the Ritter M. von Guttman (Vienna) a Knight Commander of the Order of Franz Josef ; and Mr. C. Lueg (Oberhausen) a life member of the Prussian Upper House. Mr. F. W. Lürmann has received the honorary degree of Doctor of Engineering, Berlin ; Mr. Armand Sépulchre has been created an Officer of the Order of Leopold ; Mr. C. P. E. Schneider (Le Creusot) has been created a Knight Commander of the Order of St. Ann of Russia ; Mr. R. Schott (Sheffield) and Mr. C. Svedberg (London) Knights of the Royal Order of Wasa ; Sir James Steel (Edinburgh) has had conferred upon him the dignity of a Baronetcy ; and Mr. J. H. Wicksteed has been elected President of the Institution of Mechanical Engineers.

During the year 1903 the Institute suffered heavy losses by the death of well-known members, amongst whom were several active contributors to its work. The list comprises the following thirty-nine names :—

Andrew, Henry Herbert (Sheffield)	. . .	October 13.
Bates, Henry (Salford)	. . .	January 1.
Booth, John William (Rodley)	. . .	May 19.
Bramwell, Sir Frederick, <i>Bart.</i> (London)	. . .	November 30.
Breda, Vincenzo Stefano (Terni)	. . .	January 3.
Broms, G. E. (Stockholm)	. . .	October 18.
Caine, William Sproston (London)	. . .	March 17.
Charlton, Henry (Gateshead)	. . .	February 2.
Cochrane, Henry (Cleveland)	. . .	January 16.
Davy, David (Sheffield)	. . .	April 19.
Dick, George Alexander (London)	. . .	September 18.
Downey, Alfred Christian (Middlesbrough)	. . .	April 19.
Fothergill, Richard (Tenby)	. . .	June 24.
Fox, Samson (Harrogate)	. . .	October 24.

Garrett, William (Cleveland, Ohio)	July 15.
Haehner, Pablo (Bilbao)	January 2.
Hewitt, Abram Stevens (New York)	January 18.
Hinchliffe, John (Penistone)	February.
Hollis, H. W. (Northampton)	December 2.
Houghton, John (Warrington)	March.
Kellett, William (Wigan)	February 3.
Landale, Andrew (Dunfermline)	September 16.
Lones, Jabez (Smethwick)	September 26.
Marshall, Francis Carr (Newcastle-on-Tyne)	February 24.
Morel, <i>Sir</i> Thomas (Cardiff)	October 7.
Nash, Thomas (Sheffield)	February 24.
Neilson, James (Mossend)	October 6.
Pearson, H. W. (Bristol)	October 20.
Pease, <i>Sir</i> Joseph Whitwell, <i>Bart.</i> (Guisborough)	June 23.
Price, John (Newcastle-on-Tyne)	January 27.
Rocour, George (Liège)	October 19.
Ruscoe, John (Manchester)	December.
Scott, Frederick Whittaker (Stockport)	October 22.
Stanger, William Harry (London)	February 13.
Steven, Hugh (Glasgow)	February.
Strange, A. J. (Brighton)	May.
Strick, John (Madeley)	January 22.
Thomas, William (Aberdare)	March 8.
Wendel, Robert de (Hayange)	August.

Of the deceased members Hon. Abram S. Hewitt was elected an Honorary Member in 1887, and received the Bessemer Gold Medal in 1890. Sir Joseph W. Pease, *Bart.*, was Trustee of the Institute's funds from 1880 until the grant of the Royal Charter. Mr. R. Fothergill was elected Member of Council in 1870, and Vice-President in 1875. Mr. R. de Wendel was President of the Reception Committee at the Paris meeting in 1900. Particulars of the careers of the deceased members will be found in the obituary notices published in the Journal of the Institute.

In consequence of non-payment of subscriptions the names of seven members have been removed from the list, and there have been twenty-four resignations of membership.

#### FINANCE.

The financial prosperity of the Institute is a matter for congratulation. The Statement of Accounts for the year 1903, verified by the

Auditors, is now submitted to the members by the Honorary Treasurer. It will be observed that the income for the year amounted to £5424 and the expenditure to £5205. The expenditure includes a subvention of £200 to the National Physical Laboratory, a further grant of £100 to the Engineering Standards Committee, and an annual subscription of £5 to the International Testing Association.

The corresponding figures for recent years were as follows :—

	Income.			Expenditure.		
	£	s.	d.	£	s.	d.
1902 . . .	5079	2	2	5195	16	10
1901 . . .	4580	0	0	4170	0	0
1900 . . .	4157	2	7	3771	19	7
1899 . . .	4322	10	4	3606	16	6
1898 . . .	3985	13	7	3989	16	8

#### MEETINGS.

During the year under review two meetings were held as usual. The Annual Meeting on May 7th and 8th was held at the Institution of Civil Engineers, and the constant courtesy of that distinguished body in affording accommodation demands grateful acknowledgment.

The Autumn Meeting, held for the second time since the foundation of the Institute at Barrow-in-Furness, was very largely attended and brilliantly successful. An influential Reception Committee was formed, and the excellence of the arrangements made, and the hearty welcome accorded, were highly appreciated by the members. To Mr. J. M. While, Member of Council, the Chairman of the Executive Committee, the warmest thanks for the arrangements are due. Generous hospitality was dispensed by the Mayor of Barrow, by Mr. Victor Cavendish, M.P., and by the owners of works in the district. The excursions in connection with the meeting were most instructive, and have been described at length in the Journal of the Institute.

To Mr. A. Butchart, the Honorary Secretary of the Reception Committee, whose ability and indefatigable energy contributed so largely to the success of the meeting, the Council have expressed on behalf of the members their sense of indebtedness by presenting to him a piece of plate, with a suitable inscription, in appreciation of his valuable services in carrying out the necessary arrangements for the meeting.

For the Autumn Meeting of the present year the Institute has accepted an invitation to meet in New York on October 24th to 26th. An

influential Reception Committee has been formed, with Mr. John Fritz, Hon. Member and Bessemer Medallist, as President; Mr. C. Kirchhoff, Chairman of the Executive Committee; and Mr. T. Dwight, Honorary Secretary. Remembering the great benefits derived from the previous highly successful meeting of the Institute in America in 1890, the Council look forward with confidence to a renewal of past experience.

In addition to the President's Inaugural Address and his Address read at the Barrow Meeting, twenty-eight papers were contributed to the Institute's Proceedings during the year. This total has not been exceeded in any previous year. The titles were as follows:—

1. On the Influence of Sulphur and Manganese on Steel. By J. O. ARNOLD and G. B. WATERHOUSE (Sheffield).
2. On the Influence of Silicon on Iron. By THOMAS BAKER (Wolsingham).
3. On the Determination of the Points of Allotropic Changes of Iron and its Alloys by the Measurements of the Variations in the Electric Resistance. By O. BOUDOUARD (Paris).
4. Report of the Fifth International Congress for Applied Chemistry. By B. H. BROUGH (London).
5. On Some Further Experiments on the Diffusion of Sulphide through Steel. By E. D. CAMPBELL (Ann Arbor, Michigan).
6. On the Heat Treatment of Steel. By W. CAMPBELL (New York).
7. On the Heat Treatment of Steel under Conditions of Steelworks Practice. By A. CAMPION (Englefield Green).
8. On the Open-hearth Process. By L. CUBILLO (Trubia, Spain).
9. Note on the Manufacture of Weldless Steel Pipes and Shells. By HEINRICH KERRHARDT (Düsseldorf).
10. On Alloys of Iron and Tungsten. By R. A. HADFIELD (Sheffield).
11. On the Application of the Electric Furnace in Metallurgy. By A. KELLER (Paris).
12. Notes on the Heat-treatment of Steel Rails high in Manganese. By J. S. LLOYD (Hughesoffka).
13. On the Influence of Varying Casting Temperature on the Properties of Alloys. By P. LONGMUIR (Sheffield).
14. On the Regulation of the Combustion and Distribution of the Temperature in Coke-oven Practice. By D. A. LOUIS (London).
15. On Hollow-pressed Axles. By C. MERCADER (Pittsburg).
16. On Coal as Fuel at Barrow-in-Furness. By W. F. PETTIGREW (Barrow-in-Furness).
17. On Diseases of Steel. By C. H. RIDSDALE (Middlesbrough).
18. On a New Blast-furnace Top. By A. SAHLIN (Millom).
19. On Portland Cement Manufactured from Blast-furnace Slag. By C. von SCHWARZ (Liège).
20. On the Probability of Iron Ore Lying Below the Sands of the Duddon Estuary. By JAMES LESLIE SHAW (Whitehaven).
21. On the Burning and Over-heating of Steel. By A. STANSFIELD (Montreal).
22. Note on the Alleged Cementation of Iron by Silicon. By J. E. STEAD (Middlesbrough).

23. On the Restoration of Dangerously Crystalline Steel by Heat-treatment. By J. E. STEAD and ARTHUR W. RICHARDS (Middlesbrough).
24. On Sorbitic Steel Rails. By J. E. STEAD and ARTHUR W. RICHARDS (Middlesbrough).
25. On the Development of the Continuous Open-hearth Process. By B. TALBOT (Leeds).
26. On the Effect of Flue Dust upon the Thermal Efficiency of Hot-blast Stoves. By B. H. THWAITE (London).
27. Note on the Analysis of a Specimen of Sussex Cast Iron. By THOMAS TURNER (Birmingham).
28. Report on the Mining and Metallurgical Congress at Vienna. By ALOIS WEISKOPF (Hanover).

The annual dinner of the members of the Institute was held on May 8th, at the Hotel Cecil. The chair was occupied by the President, and the principal speakers were the Prime Minister (Right Hon. A. J. Balfour), the Duke of Devonshire, Viscount Ridley, Right Hon. Sir Henry Campbell-Bannerman, M.P., Right Hon. Sir Henry Fowler, M.P., Right Hon. John Morley, M.P., Sir Samuel Chisholm, Bart., Sir James Kitson, Bart., M.P., Mr. P. de Kovacs, member of the Hungarian Parliament, and Hon. G. F. Earp, member of the Legislative Council of New South Wales.

A reception was given to the members by the President and Mrs. Carnegie at the Institute of Painters in Water-Colours on May 7th, and was largely attended.

#### PUBLICATIONS.

Two cloth-bound volumes of the Journal of the Institute have been published, containing altogether 1660 pages of letterpress, 81 plates, and numerous illustrations in the text. This amount of printed matter is in excess of that published in any previous year. In addition to the papers read before the Institute, and the discussions and correspondence relating to them, these volumes contain abstracts of 2314 papers relating to iron and steel and kindred subjects published in other home and foreign Journals and Transactions. The list of members was issued separately in the form of a pamphlet of 118 pages. For many years past it has been the practice of the Iron and Steel Institute to republish from time to time rare and interesting papers relating to the history and manufacture of iron and steel; and it having been suggested by the West of Scotland Iron and Steel Institute that it would be a useful service to metallurgy to reprint Bunsen and Playfair's report on the gases evolved from iron-furnaces read in 1845, the Council of the Iron and Steel Institute readily consented to co-operate in the work. A copy of

the reprint, with an introductory note and portraits, was forwarded to every member. The reprint covers 76 pages. Thus during the year the members received 1854 pages of printed matter.

#### LIBRARY AND OFFICES.

Numerous presentations to the Library have been made, a list of which is given in the Journal of the Institute. Although the task of selection from amongst the numerous donations mentioned is not unattended with difficulty, special attention may perhaps be directed to Mr. H. H. Campbell's "Manufacture of Iron and Steel," Mr. F. W. Harbord's "Metallurgy of Steel," and Messrs. Osmond and Stead's "Microscopic Analysis of Metals," presented by the authors, and to the profusely illustrated official record of the Düsseldorf Exhibition, presented by Mr. H. Lueg. Members who have published works valuable for reference, or pamphlets on subjects relating to iron and steel, of which they could present copies, are reminded that such contributions to the Library are highly acceptable for permanent preservation. The additions to the collection of portraits include a portrait of Sir William White, K.C.B., presented by the Organising Committee of the Complimentary Dinner to that gentleman on his retirement from the post of Director of Naval Construction; and a cast-iron bust of Professor Ledebur, Honorary Member, presented by Mr. J. Hallbauer. The collection of portraits has been enriched by the presentation by Messrs. Maull & Fox of a number of platinotype portraits of members of the Institute. Members are invited to favour Messrs. Maull and Fox with a sitting, or to present copies of their photographs in cabinet size for the Institute Album.

#### MEDALS AND RESEARCH SCHOLARSHIPS.

The Bessemer Gold Medal for 1903 was presented to Sir James Kitson, Bart., M.P., Past-President, in recognition of his conspicuous services in the advancement of the metallurgy of iron and steel.

The Andrew Carnegie Gold Medal was awarded in 1903 for the second time. The recipient was Alfred Champion of Cooper's Hill Engineering College, whose researches are described in his paper on "The Heat Treatment of Steel under Conditions of Steelworks Practice" (*Journal*, 1903, No. I. pp. 378-456).

A special medal was also awarded to Dr. O. Boudouard (Paris) in recognition of the merits of his research on "The Determination of the Points of Allotropic Changes of Iron" (*Journal*, No. I. 1903, pp. 299-377).



A large number of candidates applied for Carnegie research scholarships, and, after careful consideration, four scholarships, each of the value of £100, tenable for one year, were awarded respectively to Charles Olden Bannister (London), to Pierre Breuil (Paris), to K. A. Gunnar Dillner in conjunction with A. F. Enström (Stockholm), and to John Campbell Gardner (Middlesbrough). Further grants were also made to Alfred Campion and to Percy Longmuir (Sheffield) respectively. Particulars of the scheme have been widely distributed, and printed in the English, French, German, Hungarian, Italian, Russian, Spanish, and Swedish languages.

#### APPOINTMENT OF REPRESENTATIVES.

During the year the Institute was represented on the General Committee administering the Government grant for scientific investigations. The Right Hon. Sir Bernhard Samuelson, Bart., Past-President, and Mr. R. A. Hadfield, Vice-President, represented the Institute on the governing body of the National Physical Laboratory; Mr. Arthur Cooper and Mr. George Ainsworth, Members of Council, represented the Institute on the Engineering Standards Committee, for the incidental expenses of which a further grant of £100 was made from the Institute funds. Mr. David Evans and Mr. William Beardmore continued to serve as representatives of the Institute on the Technical Committee of Lloyd's Register. Mr. W. H. Bleckly, Hon. Treasurer, was appointed a member of the Court of the University in Liverpool as provided in the Royal Charter incorporating that University. The Institute was represented at the International Congress of Applied Chemistry in Berlin and at the Mining and Metallurgical Congress in Vienna. A selection of volumes of the Journal has been forwarded to the Royal Commission for the St. Louis Exhibition to form part of the exhibit of metallurgical literature. A party of members of the Liège Society of Engineers, the society that entertained the Institute in 1873 and in 1894, having intimated their intention of visiting London on September 12, the Council has decided to take steps to ensure them a cordial welcome. A congratulatory address was forwarded to Professor Wedding, Hon. Member and Bessemer Gold Medallist, on the celebration of his jubilee as a metallurgist.

#### RETIRING MEMBERS OF COUNCIL.

The retiring Members of Council, whose names were announced at the Barrow Meeting, are :—*Vice-Presidents*: Sir J. G. N. Alleyne, Bart.; Mr. G. J. Snelus, F.R.S.; and Mr. James Riley. *Members of*

*Council*: Mr. William Beardmore, Mr. David Evans, Mr. Victor Cavendish, M.P., Mr. Arthur Cooper, and Mr. W. Evans.

Owing to the election of Mr. Carnegie as President, a vacancy arose on the Council, which was filled by the election of Sir Benjamin Hingley, Bart., as Vice-President, and of Mr. John M. Gledhill of Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester, as Member of Council. As no other members were nominated up to one month previous to this meeting in response to the announcement made at the Barrow Meeting, the retiring Members of Council are presented for re-election.

## HON. TREASURER'S REPORT.

The Hon. Treasurer (Mr. W. H. Bleckly) submitted the following report:—

It is with much satisfaction that I have to report the past year's income as being the highest recorded in the history of our Institute, and I think you will agree with me that it is not any reflection upon the management of your finances that our expenditure was also the largest which has ever occurred. It is also satisfactory to be able to tell you that at the end of our financial year we have a credit balance to bring forward amounting to £219, 2s. 10d., which more than wipes out our last year's deficit of £116, 14s. 5d. The expenditure of 1903, omitting shillings and pence, amounted to £5205, while the receipts from all sources were £5424, leaving a surplus of £219.

There was an encouraging increase in the receipts from entrance fees and subscriptions, whilst diminished taxation resulted in an increased return for interest on investments. The only item of revenue showing a decrease is the inevitably fluctuating amount received from the sales of the *Journal* to the public. This amount was, however, £37 above the average of the last five years. The decrease, which I may fairly call more apparent than real, is largely due to the fact that in 1902 the amount named included the proceeds of the sale of the General Index.

The expenditure calls for little comment, the increase being mainly attributable to the steady growth of membership, upon which we may congratulate ourselves. This is naturally accompanied by increased cost of correspondence, printing, and postage.

The cost of the *Journal* also shows an increase, but this, in my opinion, is in no way unsatisfactory, as it arises from the larger number of *Journals* printed and an additional number of pages of interesting, instructive, and useful matter.

The cost of our usual meetings was not above the average of previous years.

1904.—i.

B

## THE IRON AND STEEL INSTITUTE.

## ACCOUNT OF INCOME AND EXPENDITURE FOR THE YEAR ENDED DECEMBER 31, 1903.

INCOME.		EXPENDITURE.	
To Entrance Fees . . . . .	£ 386 0 0	By Salaries . . . . .	£1295 0 0
" Annual Subscriptions . . . . .	9680 18 0	" Office Rent, Cleaning, &c. . . . .	403 8 6
" Life Compositions . . . . .	189 0 0	" Library Books and Binding . . . . .	82 8 7
" Journal Sales . . . . .	279 6 4	" Office Furniture . . . . .	8 9 1
" Interest on Investments . . . . .	801 14 1	" Annual Meeting (London) . . . . .	82 19 4
" Bessemer Metal Fund Interest . . . . .	15 1 8	" Autumn Meeting (Barrow) . . . . .	224 0 1
" Interest on Deposit . . . . .	47 15 4	" Journal Publishing Expenses :—	
" Sundry Receipts . . . . .	0 2 0	Printing . . . . .	£1890 18 2
" Carnegie Scholarship Fund :—		Abtracts . . . . .	172 15 0
Interest on Bonds . . . . .	624 11 5	Translations of Papers . . . . .	23 9 0
		Postage . . . . .	120 11 0
		Stationery and Printing (including copies of papers) . . . . .	1647 13 2
		" Postage and Receipt Stamps . . . . .	382 15 11
		" Insurance . . . . .	126 15 8
		" Bessemer Metal . . . . .	1 15 0
		" Grant to National Physical Laboratory . . . . .	15 5 0
		" Grant to Engineering Standards Committee . . . . .	200 0 0
		" Grant to International Testing Association . . . . .	100 0 0
		" Travelling Expenses . . . . .	5 0 0
		" Sundry Payments . . . . .	51 19 2
		" Auditor's Fee . . . . .	33 8 7
		" Carnegie Scholarship Fund :—	12 12 0
		Scholarships . . . . .	£500 0 0
		Medals . . . . .	18 7 7
		Printing and Stationery . . . . .	14 9 7
		Advertising . . . . .	5 6 8
		Translations . . . . .	17 12 6
		Balance, being excess of Income over Expenditure :—	583 15 11
		General Fund . . . . .	£148 7 4
		Carnegie Scholarship Fund . . . . .	70 15 6
			219 2 10
			£5424 8 10

## To Sundry Creditors :-

LIABILITIES.		ASSETS.	
Journal Printing and Publishing	£264 8 3	By Subscriptions in arrear, since received	£26 2 0
Library Postages	58 10 3	" Entrance Fee	2 2 0
Office Books and Binding	18 8 0	" Interest on Investments accrued, due at	
Office Rent	108 5 10	31st December 1903	150 5 7
Printing and Stationery	36 14 8	" Interest on Deposit accrued due at 31st	
Carnegie Scholarship Fund—		December, 1903	17 5 10
Scholarships due	100 0 0	" Journal Sales, since received	
Printing Account due	2 4 4	" Cash paid on Account of Autumn Meeting, 1904	
Subscriptions in advance		" Cash on Deposit	1619 12 10
Iron and Steel Institute Capital Account as at		" Do. on Current Account	147 15 4
1st January 1903	£291 16 5	" Secretary's Balance :—	
Add Excess of Income over Expenditure	148 7 4	At Bank	£181 13 2
	1180 8 9	In hand	10 10 1
Carnegie Scholarship Fund :—			1959 11 6
Balance of Income not expended at 1st Jan-			
uary 1903	£115 14 11		
Add Excess of Income over Expenditure	70 15 6		
	186 10 5		
	£2344 15 4		£2344 15 4

## INVESTED FUNDS OF THE INSTITUTE.

£2744 North-Eastern Railway 4 per cent. Preference Stock, purchased at a cost of	£4297 6 7
£788 North-Eastern Railway 4 per cent. Guaranteed Stock, purchased at a cost of	1008 14 0
" B " Annuity £79, 4s. 6d. Sindh, Punjab, and Delhi Railway, expiring 1968, with a Sinking	1999 0 7
Fund to replace the amount of Stock, purchased at a cost of	
" B " Annuity of £50, 1s. 8d. Great Indian Peninsula Railway, expiring 1948, with a Sinking Fund	1287 6 0
to replace the amount of Stock, purchased at a cost of	751 2 0
£700 Middlesbrough Corporation Waterworks 3½ per cent. Debenture Stock, purchased at a cost of	£9823 9 2

## ANDREW CARNEGIE RESEARCH SCHOLARSHIP FUND.

£84,000 Pittsburg, Bessemer & Lake Erie Railroad 5 per cent. Debenture B nda.

(Signed) W. H. BLECKLY, *Hon. Treasurer.*

BENNETT H. BROUGH, *Secretary.*

I have examined the above Accounts with the Books and Vouchers of the Institute, and certify them to be correct. I have also verified the Balances at the Bankers and the Securities for the Invested Funds as shown above.

(Signed) W. B. KEEN,  
*Chartered Accountant.*

8 CHURCH COURT, OLD JEWRY, LONDON, E.C., April 18, 1904.

## BESSEMER MEDAL FUND.

£534 London and North-Western Railway 3 per cent. Debenture Stock.

The extraordinary expenditure comprises subventions of £200 to the National Physical Laboratory, £100 to the Engineering Standards Committee, and £5 to the International Testing Association.

With regard to the Carnegie Scholarships Fund the position is thoroughly satisfactory. The income for the past year was £624, 11s. 5d., and the expenditure £553, 15s. 11d., leaving a small balance to bring forward.

In conformity with the usual practice, I have to report that, in company with Mr. Brough and our auditor, Mr. W. B. Keen, I visited the strong room of our bank and verified our securities, which Mr. Keen certifies as of the total market value, on the 31st of December 1903, of £9253. The amount they stood at in our books at that date was £9323, 9s. 2d. The auditor has also given his usual certificate regarding the correctness of the accounts.

We seldom look ahead very minutely in regard to prospective expenditure, but it is perhaps well to draw your attention to the fact that during the current year our visit to America will in all probability cost more than one of our ordinary autumn meetings, but I am sure that the members of this Institute, after the excursion is over, will not grudge to pass the accounts.

The PRESIDENT said that the members had now heard both the Report of the Council and that of the Honorary Treasurer. He could not see that any one could complain as far as the budget of the Institute was concerned. Its receipts had been greater than they had ever been before. He moved that the Report and Statement of Accounts be accepted.

Sir LOWTHIAN BELL, Bart., Past-President, seconded the motion, which was carried unanimously.

Mr. H. BAUERMAN (London) proposed that the thanks of the meeting be presented to the President and Council for their services during the past year. The list of papers showed how carefully the work had been arranged, and he noticed one gratifying feature, which was that they had instituted the reprinting of old memoirs to a certain extent. As an old pupil of Lord Playfair very many years ago, he could remember how very eloquent his lordship used to be about the waste of fuel in the

blast-furnace. They knew now from the works of Sir Lowthian Bell that some of the deductions were not irreproachable, but still they were the first to give a quantitative idea of the waste of fuel in the tunnel head flame of the blast-furnace of that period. In this connection the show of pyrometers that had been arranged would be very useful. He would also refer to Mr. Blass' paper on flame temperatures, published in 1892, which was the very first of the physical demonstrations of possible flame temperatures. He moved a vote of thanks to the President and Council.

Mr. A. LAMBERTON (Coatbridge, N.B.) said he had very great pleasure in seconding the vote of thanks which the Institute had to accord to the President and Council, who during the past year had so loyally given their services for the benefit of the Institute. He was sure they were all agreed that when it became known that Mr. Carnegie had seen his way to accept the honour which the Institute sought to confer upon him in asking him to become President, the knowledge of this was received throughout the land with the very greatest possible satisfaction, and their hopes and expectations rose accordingly. Now after a year of his presidency he was sure they all felt that those hopes and expectations had been far more than amply realised, and that in Mr. Carnegie they had an altogether exceptional President. He seemed to be one of those very few gifted men who, no matter what position they might be called upon to fill, filled it with the utmost distinction, and he was sure that the Institute were now delighted to accord a very hearty vote of thanks to Mr. Carnegie and the other gentlemen of the Council, who had given so much of their time and talents to the conduct of the business during the past year.

The PRESIDENT said, in reply, that on behalf of himself and the Council he might recall the words with which Lady Macbeth greeted the King: "All our service in every point twice done, and then done double, were poor and single business to contend against those honours deep and broad wherewith you load us."

## PRESENTATION OF THE BESSEMER GOLD MEDAL.

The PRESIDENT then proceeded to present the Bessemer Gold Medal to Mr. R. A. Hadfield, Vice-President of the Institute.

He said: This Medal has been presented before to distinguished men who have done great service, but I make bold to say that it never has been presented with greater unanimity, with stronger belief that we have found in you, sir, a worthy recipient of the greatest honour which it is in our power to bestow. It were superfluous in me to recount your history and your achievements before those who know you so well. Your career is one of which any man might well be proud. The test of success is the man's position in the line in which he chooses to attack and to conquer. The greatest physician in the world is necessarily one of the greatest of men. The greatest orator, the greatest scientist, the greatest musician or statesman is the man at the top of his profession, and beyond that there is no other test, because the greatest Prime Minister that ever lived cannot be compared except upon an equality with the greatest man in any other important line. They are all at the head. They sit on the same platform; and you, sir, have achieved the rare distinction of being foremost in the line which you have chosen and mastered. You have a unique establishment. It is not equalled as far as I know in the world in its special line; and therefore, sir, we bow before you as a master among men. I do not know what you are going to do hereafter. There is this regret that you must have in your own mind, that having achieved this position so early, there are no other heights to climb. But I know this will not be deadening to your energies. The man who becomes a master in anything is eventually mastered by the ambition that impelled him on, and which makes him its slave; and you will continue to labour as you have done in the past, and achieve other distinctions and other triumphs. May I upon this occasion venture to remind the Institute that we of the other branch of the race in America wish to put in our claim to share in the honour bestowed upon this pure Briton of the Britons. Gentlemen, I take unusual pleasure therefore in the Institute having gone so far as to venture upon an Anglo-American President; that it goes

onward and bestows its Bessemer Medal upon one whose wife is an American, which makes Mr. Hadfield like myself an Anglo-American. I take it that you and I and others having interests and affections and love for both branches of our race may stand before the world as ties, binding the two branches together in a friendship which is never to be marred by the slightest friction; that as the two branches of our race go forward in the world to the great work before them they will go hand in hand. So, sir, say to your wife, when you take home this Medal, that it is not solely British, but British-American, a joint possession to be treasured as one of the heirlooms of your family. We wish you all good fortune.

Mr. R. A. HADFIELD, Vice-President, in reply, said: I find it most difficult indeed to adequately express my thanks and appreciation of the high honour which this great Institute, with its roll call of metallurgists throughout the world, has seen fit to confer upon me to-day; and to you, sir, for your more than kind remarks to myself, may I add that I regard this great honour not merely as a personal one, but as also given to me as a representative of this great city from which I have sprung—Sheffield—where more than 140 years ago Huntsman first made steel, and which is still the leading centre in the world for the highest quality of material and wide range of special products. I know of only one objection to the Bessemer Medal, and that is, it should have been made of Bessemer's steel rather than of gold. If it were only possible to obtain some of Bessemer's original or first product from which to make the medals presented each year, how much more precious than gold would have been such a memento of a name and a material which has helped to revolutionise the world. This honour, so much prized, carries with it responsibility of no mean order. I can only claim your indulgence in the future as in the past, for the Bessemer Medal carries with it no charm, "*Humanum est errare*" still remains. All I can say is that it will be my endeavour to continue to do all in my power to assist the advancement of our noble art of metallurgy. It is, Mr. President, specially gratifying to receive the medal at your hands, coming as you do from the great Republic over the



sea, whose aspirations and aims are very similar to ours here. I have, sir, on so many occasions received there such kindly encouragement and assistance that it is indeed most pleasing that you have placed in my hands the distinction admitted by all to be the blue ribbon of the metallurgical world. May I add that I shall never forget the manner in which you, Mr. President, received me more than fifteen years ago at your own country house in Cresson Springs, in the Alleghanies, and the kindly words of encouragement you gave me on business matters I was then developing. May I take this opportunity of wishing you, as representing America here, the greatest possible success to your St. Louis Exhibition, probably the most marvellous the world has ever witnessed.

May I also express my deep sense of personal gratitude to the many friends on the Council and in this Institute who have during my connection with it always held out a friendly hand to me—one of its younger members. To my friend, Sir Lowthian Bell, the Nestor of metallurgy, whom we are so delighted to see here to-day, I am specially grateful. Need I here say, as one of the younger members of the Council, that if I can at any time help on our younger members of the Institute, how glad I shall be to do all in my power. Finally, as to any merit in my work that this Institute has seen fit to consider exists, I can only say if merit there be that it has been entirely due to persistent hard work. The labour involved in metallurgical research is great, but is not the cause also a great one, for what would the world to-day be without the labours of the metallurgist? As regards my work on alloys of iron and steel, at the time I presented my first alloy research—that on the discovery of manganese steel—the systematic study of alloys of iron with other elements was practically virgin ground, but I freely acknowledge the great assistance and co-operation I have had from time to time from a host of friends, from the most eminent physicists, chemists, and brother metallurgists. To mention only a few I would express my special indebtedness to Mr. Osmond, Prof. Barrett, Dr. Sorby, Dr. Fleming, Prof. Kennedy, Prof. Arnold, Mr. Stead, the late Mr. J. F. Barnaby, Prof. Ledebur, Prof. H. M. Howe, and many others. To members of my own staff—alas, some of them gone from

us—I have been most greatly indebted, as in season and out of season they have ever been ready to give their most loyal assistance and co-operation. As of historic interest I have placed on the table to-day specimens of the first manganese-iron alloy I made twenty-two years ago, on 25th September 1882, and which, if you wish, Mr. President, I shall be very pleased to present to the Institute. They represent the three critical points of the manganese-iron alloys, namely, the brittle percentage containing about 5 per cent., the very tough product about 11 per cent., and the harder one 17 per cent. of manganese. Mr. Osmond has been good enough to say that this discovery of mine “has not been merely the discovery of a new alloy, curious and yet useful, but that it ranked as a discovery equal in importance only to that of the effect of quenching in the history of the metallurgy of iron, the only one of the same order which it had been reserved for our age to make.” Certainly a material which subverted all previous metallurgical ideas and was found non-magnetic, hard yet tough, not hardened by quenching, as well as having other peculiarities, was at the time of its discovery, 1882, not a little remarkable.

#### THE ANDREW CARNEGIE GOLD MEDAL AND RESEARCH SCHOLARSHIPS.

The SECRETARY reported that having carefully investigated the numerous applications received, the Council decided that Andrew Carnegie Research Scholarships of the value of £100 be awarded to John Dixon Brunton (Musselburgh); H. C. H. Carpenter, M.A., Ph.D. (National Physical Laboratory); E. G. L. Roberts and E. A. Wraight, conjointly (London); Frank Rogers (Cambridge); and Walter Rosenhain, B.A. (Birmingham); and that a grant of £50 be made to O. Boudouard (Paris).

Extension of time for the completion of their reports has been granted to the Carnegie Scholars of 1903, with the exception of Pierre Breuil (Paris), to whom the Gold Medal is awarded. A special silver medal is awarded to Percy Longmuir (Sheffield), in appreciation of the research carried out by him with his renewed grant.

The following is an account of the careers of the recipients of the Andrew Carnegie Research Scholarships for 1904 :

JOHN DIXON BRUNTON studied for four years in the Metallurgical Department of University College, Sheffield, and is now manager of W. N. Brunton & Son's Wire Mills, Musselburgh.

HENRY CORT HAROLD CARPENTER studied at Oxford for three years, at Leipzig for two years, and at Manchester for one year. For the past two years he has been Assistant in the Metallurgical Department of the National Physical Laboratory.

EDWIN GILBERT LLEWELLYN ROBERTS studied at the City and Guilds of London Institute at Finsbury, and at the Royal School of Mines. He is now Demonstrator in Metallurgy at the latter Institution.

ERNEST ALFRED WRIGHT studied at the Royal School of Mines, where he is now Demonstrator in Metallurgy.

FRANK ROGERS, B.Sc., studied at University College, Liverpool, and obtained an 1851 Exhibition Scholarship, which he is holding at Cambridge.

WALTER ROSENHAIN studied at the University of Melbourne, and has carried out some important researches with Professor Ewing at Cambridge. He is now Scientific Adviser to Chance Bros. and Co., Ltd., Birmingham.

OCTAVE BOUDOUARD is Demonstrator of Chemistry at the College of France. He has received the medals of the Société d'Encouragement and of the Chemical Society for research, and received a special Carnegie Medal from the Iron and Steel Institute in 1903.

PIERRE BREUIL, who receives the Andrew Carnegie Gold Medal, was for five years in charge of the laboratory for the mechanical testing of metals for the Paris, Lyons, and Mediterranean Railway. He is now Director of the Testing Laboratory of the Conservatoire des Arts et Métiers.

PERCY LONGMUIR studied at University College, Sheffield, and has had a practical training in foundry work. He received a Carnegie Research Scholarship in 1902, which was renewed in 1903. He is now assistant at the National Physical Laboratory.

The PRESIDENT read a letter from Mr. Breuil, addressed to the Secretary, which was as follows: "Dear Sir,—I scarcely

know how to give expression to the extreme gratification afforded to me by your kind letter, and words fail me with which to convey the sense of my deep gratitude to your President and Council for their recompense of my labours. This acknowledgment of my work has indeed caused me the most profound pleasure. I may, however, perhaps state that what really affords me the chief pleasure of all is, not that I have had the honour of being selected for the award of the great favour you have been pleased to bestow upon me, nor even that I see enhanced the name of my laboratory; it is the thought of the profound joy which will be experienced by my parents, two good French peasants, now advanced in years, poor and infirm, and living in a remote country village, on learning that their son has achieved so high a mark of distinction."

On Mr. Breuil coming forward to receive the Gold Medal the PRESIDENT said: Mr. Breuil, I have many times regretted that in my youth I did not learn your beautiful language that I might address you on this occasion. But there is a language of the heart in which I can speak to you, and of the head, that is a universal language. I now speak to you in my native tongue only because I do not know yours sufficiently well to express myself freely in it. France has from the earliest days been the favourite friend of one branch of the English-speaking race—the American. Recently France and Britain have become friends. I believe they are to continue growing in friendship. The two neighbours with only twenty miles between them are getting to know each other more and more, having more ties between them, and you to-day make another. I hope we shall never know anything but generous rivalry in the domain of peace, and the acquisition of knowledge. I have just returned from Paris, where I met some of the men for which France is famous. Pasteur has passed away. I met his successor, who was so suddenly stricken down the day before yesterday. I saw him in good health. I have been with Berthelot, your great scientist of world-wide fame. I have been with Monsieur Curie and his wife, the discoverers of radium. What a class of men you gave the world, men disdaining wealth, refusing patents for anything they do. Declining rank when it was in their power to attain it, they have led simple lives, dedicating themselves to the service

of their fellow-men. Living in poverty they have realised Franklin's rule of life, "The highest worship of God is service to man." I think your country, France, stands in the front rank in introducing such individuals. But, sir, we are not without them in the English-speaking races. I could mention many names. I will take the great liberty of mentioning one, our first honorary member, who happens to be here present, Professor Bauerman. I believe he is a fit colleague to Pasteur, Berthelot, and Curie; such men labour not for what we meaner men consider the crown of victory, but for that higher crown which disdains the allurements of society and rank and wealth. They live pure, simple lives, having for their end not self-gratification but the well-being of their fellow-men. I congratulate you most heartily, I am delighted that you are a Frenchman, and hence that this is another tie between France and Britain. Thank you for your letter, and, believe me, all through your life you can keep the cheering assurance that every man of the Iron and Steel Institute wishes you well.

#### PRESENTATION OF SPECIAL CARNEGIE MEDAL.

The PRESIDENT, addressing Mr. Percy Longmuir, then said: You are one of those engaged in discovering the mysteries of steel, and you have made some rare discoveries. The Institute thinks so highly of these that they have thought fit to present a special medal to you—I think a rare distinction for so young a man, an earnest, perhaps, of what is coming. Some day the colour of the medal may be slightly different, but I do not think that the success will be more brilliant, because this is a special medal, whereas the other is one that will come in its natural course. I agree with the recipient of the Bessemer Medal (Mr. Hadfield), that it would be wonderfully fine if we had some of the original material of the Bessemer converter instead of gold for the Bessemer Medals. It is too late. This medal does not shine. You remember in the *Merchant of Venice*, when Bassanio had to choose from the three caskets. When he saw the gold one he called it "hard food for Midas," and rejected it. Then he rejected the silver as "a pale and common drudge"; and then he came to the dull leaden colour, somewhat resembling this medal,

and in that casket he found the priceless gem of which he was in search. I trust it will be so with you. If you do not get a gilded medal, you have one, perhaps, of more solid quality. At all events it is a special medal, and you have been considered by the unanimous vote of the Council worthy of it. We give it predicting for you, sir, a great career in the future. You have begun well, and a good beginning is half the battle. In the other half of the battle of life we expect to find you in the front rank of service to your fellows, and the proud winner of many honours.

The following paper was then read:—

## EXPLOSIONS PRODUCED BY FERRO-SILICON.

BY A. DUPRÉ, PH.D., F.R.S., CHEMICAL ADVISER TO THE EXPLOSIVES DEPARTMENT, HOME OFFICE, AND CAPTAIN M. B. LLOYD, R.A., H.M. INSPECTOR OF EXPLOSIVES.

### I. CIRCUMSTANCES OF THE EXPLOSIONS.

HAVING in view the extent to which ferro-silicon is in use, it seems that it is a matter of some importance that the Institute should be in possession of the particulars of several explosions which occurred in connection with a consignment of this material from the Cunard Company's steamship *Veria* at the Alexandra Dock, Liverpool.

The vessel, which had brought a cargo from Triest, was discharged on the 17th December 1903, and owing, it is said, to a fire having occurred on the vessel, the ferro-silicon was detained on the quay until the 12th January, when Messrs. Beck & Co., of 61 South John Street, Liverpool, removed the forty-eight drums, in which the ferro-silicon was contained, to a warehouse in Dacre Street, Bootle.

They were seen there on a lorry by Inspector Jones of the Explosives Department of the Liverpool Police, whose attention was drawn to them by the strong smell of acetylene gas; this smell, as will be shown, was doubtless due to phosphoretted hydrogen, the unpleasant odour of ordinary acetylene being due to the presence of traces of this gas. Shortly after, whilst a drum was being rolled from the truck on to the concrete floor of the warehouse, a violent explosion occurred followed by flame. The drums were then removed to an open yard, and during this removal a second drum exploded.

It was then considered advisable to place the ferro-silicon in wooden barrels; this was done, and holes were said to have been bored in the end of the casks to prevent the accumulation of any inflammable gas. These measures were however of no avail, for on the 21st January a porter employed by the Liverpool Warehousing Company was engaged in weighing some of

the barrels and was in the act of removing one from the machine when it exploded. The barrel was blown to pieces, and the man was thrown seven or eight yards away, and being severely bruised was removed to hospital.

## II. CAUSE OF THE EXPLOSIONS.

A sample of the ferro-silicon was obtained by us through the head constable of Liverpool, and was submitted to an examination with a view to ascertaining the cause of the explosions. This examination showed that :—

The substance when moistened evolved, even in the cold, an inflammable gas which consisted at any rate in far greater part of phosphoretted hydrogen.

Neither acetylene nor siliciuretted hydrogen could be detected, and at most minute traces only of these gases could have been present. (Ferro-silicon yields no siliciuretted hydrogen with water but only when acted on by strong acids.)

For the determination of the cause of this explosion the exact composition of the gas is not a matter of essential importance, the main point is that the gas is inflammable and forms an explosive mixture with air. Experiment has shown that 4 kilogrammes of the powdered ferro-silicon will make 64 litres of air explosive. Its temperature of ignition is low, considerably below a red heat; indeed, pure phosphoretted hydrogen ( $\text{PH}_3$ ), which is not spontaneously inflammable, is stated to ignite at a temperature of  $200^\circ \text{C}$ .

Such a temperature may, we think, very well be produced by the friction of the irregularly shaped hard lumps of ferro-silicon, either against each other or against the sides of the drum, when subjected to rough treatment.

The experiments were made by one of us with small quantities of finely powdered material; but that brings in mainly the element of time, and moreover in the case of a hard and brittle material like this, a quantity of more or less fine powder is sure to be produced during transport.

The gas evolved by treatment with water ignites when it



comes into contact with strong nitric acid. In none of our experiments, however, did the phosphoretted hydrogen evolved inflame spontaneously; it is, however, well known that when produced under certain conditions it is liable to spontaneous ignition.

From these considerations we have therefore formed the opinion that the explosion was most probably caused by water having got into the interior of the drums; the gas evolved formed, with the air in the drums, an easily ignited explosive mixture, which was fired by the heat produced by the friction of the hard lumps against each other when the drums were moved about, or possibly by the spontaneous ignition of some phosphoretted hydrogen contained in a pocket in the material, and liberated suddenly by the breaking of a lump on the drum being moved.

Mr. G. Watson Gray, who read a note on this subject at a meeting of the Faraday Society on the 2nd February, also attributes the explosion to the presence of phosphorus; but he found acetylene and arseniuretted hydrogen among the gases generated in the casks, though he did not apparently find any acetylene in the gases generated by the sample which he boiled with water in his laboratory.

Mr. Watson Gray, whose experience in metallurgical analysis is well known to the members of this Institute, has kindly furnished us with the results of his analysis of a piece of the metal.

These are as follows :—

	Per Cent.
Silicon . . . . .	59·40
Iron . . . . .	36·85
Manganese . . . . .	0·08
Aluminium . . . . .	2·73
Calcium . . . . .	0·14
Magnesium . . . . .	0·17
Carbon . . . . .	0·218
Sulphur . . . . .	trace
Phosphorus . . . . .	0·066

The results of this analysis, when compared with those given by him in his paper on the "Presence of Calcium in High Grade Ferro-Silicon,"\* tend to show that the sample was of more

\* *Journal of the Iron and Steel Institute*, 1901, No. II. p. 144.

than average purity, the percentage of foreign substances being under 4 per cent., whereas in none of those referred to is that percentage much below 7 per cent., and that only with a low proportion of silicon; but it should be noted that although the percentage of calcium is lower, that of phosphorus is higher in this case than they are respectively in any of those reported in Mr. Watson Gray's paper.

### III. PRECAUTIONS TO AVOID RISK IN FUTURE.

It would appear, therefore, that these explosions are probably due, not to the ferro-silicon itself, but to the presence of impurities, and more particularly to the phosphorus compounds contained in it. The best method of avoiding such risks in future would be to use such materials only as are free from phosphorus, or if this be found impossible, to fill up the drums with paraffin oil of high flashing point. The drums used should, as an additional precaution, be perfectly water-tight, and of such strength and construction as not to be liable to become insecure under the ordinary conditions of transport.

An alternative precautionary measure would be only to send solid ingots well tarred and packed in drums as above described, but we have no means of knowing whether such a measure would be practicable.

Drums suitable for packing the broken ferro-silicon are already in common use for the purpose of packing carbide of calcium, though we should be sorry to be taken to mean that any carbide drum will fulfil the requirements, many of those in use, particularly some of foreign manufacture, being considerably below a desirable standard.

In conclusion we would point out that although the accident now under consideration was not attended with any very grave results, the possibility of an explosion on a far larger scale must not be lost sight of. It is important, therefore, that all those who have to store or handle this substance should be fully alive to the possible dangers attaching to it, and by keeping it in a dry and thoroughly well-ventilated place, prevent the accumulation of inflammable gas as far as possible. We would suggest also that all products of an electric smelting-furnace should be

treated with similar precautions until such time as enough is known about them to be certain that these risks do not attach to them.

We cannot conclude without expressing our appreciation of the kindness of Mr. Watson Gray in furnishing us with the results obtained by him and allowing us to use them for the purposes of this paper.

NOTE.—Between the time this paper was first sent in and the time it was read at the meeting, we carried out further experiments which were suggested to us by Capt. Thomson, H.M. Chief Inspector of Explosives. These experiments showed that a sample which would approximately pass through a  $\frac{1}{4}$ -in. mesh, continued, when kept under water, to evolve gas for about a week; but one which was kept in a solution of common salt (NaCl) evolved gas slowly, but continuously, for six weeks, the whole time that it was under observation. The addition of salt to the water in which the first-mentioned sample was kept caused it to recommence generating gas. A similar effect was produced by a solution of magnesium chloride. In view of these experiments we have withdrawn the recommendation which appeared in the advance copy of the paper, to treat the ferro-silicon with water in order to decompose any gas-generating substances which it might contain. Such treatment probably would be quite ineffectual in protecting it from water containing salt or magnesium chloride (*e.g.* sea water); and in view of the length of time during which generation was observed with the finely divided sample in ordinary water, the treatment could hardly be efficacious on a large scale.

*DISCUSSION.*

Mr. G. WATSON GRAY (Liverpool) said he was pleased to hear that the authors had come to practically the same conclusion as he had with regard to the gas causing the explosion. When he read his note on this subject before the Faraday Society, some of the gentlemen who took part in the discussion were very loth to believe that the explosion was caused by phosphoretted hydrogen. They seemed to think that it was more likely to be due to acetylene formed from calcium carbide, which had got into the ferro-silicon by its being made in furnaces which had been previously used for the manufacture of carbide, and had not been cleaned out before the ferro-silicon was made.

At first glance it seemed difficult to believe that such a large volume of phosphoretted hydrogen should be evolved when there was such a small percentage of phosphorus in the sample. It appeared to him that a likely explanation would be that the phosphoretted hydrogen was itself occluded or condensed in the material, as when it was heated below a red heat the gas was evolved without the presence of water. If this were the case probably the phosphorus shown in the analysis was low, as in grinding the samples down to a fine powder the occluded gas would most likely be lost. Many ferro-alloys made in the electric furnace gave distinct odours of hydrocarbon gases in the process of grinding them for the purpose of analysis, and therefore this strengthened the idea of occluded gases, as there was no water added to the samples in grinding.

From a casual glance at the contents of the casks of this parcel of ferro-silicon, there was nothing unusual to notice. There were the usual lumps and small, and, as is common with the majority of 50 per cent. ferro-silicons, the lumps were friable.

On a closer examination he however found that some pieces of the ferro-silicon in the cask which exploded on 21st January contained unreduced quartz embedded in the ferro-silicon. He had never previously observed any unreduced quartz. He also found this cask to contain some pieces of slag from a ferro-silicon furnace, and likewise some small pieces of paraffin wax. The presence of the paraffin wax was accounted for by the maker's knowledge of the liability of 50 per cent. ferro-silicon to disinte-

grate, and it had been their custom to dip it in melted wax, with the view of keeping it from air and moisture and preventing disintegration. It, however, did not fulfil the object in view; disintegration continued and gases were liberated, as the present case fully proved.

Since giving Dr. Dupré an analysis of this ferro-silicon, he had completed the analysis (No. 2) of an average sample of the contents of the actual cask which violently exploded on 21st January, and he had also completed an analysis (No. 3) of the lump of ferro-silicon upon which he experimented to obtain the gas.

	No. 2. Per Cent.	No. 3. Per Cent.
Silicon . . . . .	53·80	55·08
Iron . . . . .	41·27	41·70
Manganese . . . . .	0·10	0·06
Aluminium . . . . .	3·47	2·67
Calcium . . . . .	0·10	0·09
Lime . . . . .	0·56	nil
Magnesium . . . . .	0·06	0·05
Carbon . . . . .	0·49	0·15
Sulphur . . . . .	0·01	trace
Phosphorus . . . . .	0·069	0·104

It would be noticed that the analysis No. 2 showed calcium 0·10 and lime 0·56, whereas No. 3, which was a lump from the same cask, but quite clean, showed calcium 0·09 and no lime. The lime found in No. 2 was no doubt a portion of the slag and had played no part in causing the explosion; for while No. 3 contained no lime, it was from this piece that he obtained the ready supply of gas on boiling it in water. It was therefore evident that the calcium and lime had played very little, if any, part in the generation of the gases.

It seemed to him that the manufacturer must aim at making, if it were possible, the 50 per cent. more adherent. Some claim that they can now do so. The lower grades, 25 to 40 per cent., and the higher grades, 65 to 85 per cent., even when they were charged with 14 per cent. calcium, did not disintegrate, for he had kept pieces exposed to the varying atmospheric conditions of his laboratory for over three years without the least sign of change, and if the 50 per cent. could not be made adherent it would be better to make and use 75 per cent. silicon, as Mr. Keller, in his paper last May, said the ratio of cost was not increased.

Mr. J. E. STEAD, Member of Council, said that he had a sample of this peculiar material sent to him immediately after the explosion took place in Liverpool, and had examined it with very great interest. He found that the peculiarity was the presence of phosphide of calcium. The specimen, which he had subjected to a searching test, yielded gas which contained about 50 per cent. of acetylene and 50 per cent. of phosphoretted hydrogen. The distilled water in which he had placed the metal became very strongly alkaline, owing to the presence of lime with some magnesia. The sample disintegrated into crystalline particles, but it was not until nearly a month had elapsed that disintegration and generation of gas entirely stopped. The interest attached to this case was the proof afforded that the phosphides of the alkaline earths were soluble in liquid ferro-silicon, and were thrown out of solution just as bismuth is thrown out of copper at the solidifying point, and that just as the bismuth is found enveloping the crystals of copper, in like manner the alkaline earth phosphides formed envelopes round the crystals of the ferro-silicon. Water on coming into contact with the envelopes re-acted on the phosphide of calcium, of which they were mainly composed, producing lime and phosphoretted hydrogen and a complete disintegration of the mass. It was most interesting from a metallurgical point of view to know that a portion of the phosphorus, if not all of it, under such conditions combines with calcium in preference to the iron.

Mr. F. W. HARBORD (Cooper's Hill) said that he recently visited several works where ferro-silicon was being made in an electric furnace, and directly he received a copy of the paper he had written off to two different works and asked them to send him samples varying in silicon. He received several samples containing from 30 to 80 per cent. only a few days ago. He crushed the rich alloy up and put it into water, but got no gas off, at all events until after twenty-four hours. On heating he got a small quantity of phosphoretted hydrogen, confirming the authors results. With reference to the suggestion of packing the material in tar, or rather tarring the ingots, he did not think that was feasible, because many of the rich alloys were extremely

brittle, and they disintegrated and fell to pieces on cooling, so that it would not be possible to ship them in the form of large ingots.\*

Professor H. LE CHATELIER (Paris) thought the explanation given by the authors to account for the explosions occasioned by ferro-silicon by an evolution of phosphoretted hydrogen hardly seemed plausible. Analyses of samples had yielded only traces of phosphorus (·06 per cent.), and it would be difficult to explain the presence of a greater proportion of phosphoretted hydrogen from such a small quantity, particularly as the presence of phosphorus is as carefully avoided in the manufacture of ferro-silicon as in that of calcium carbide. It would be much more likely that the explosions in question were to be attributed to siliciuretted hydrogen, one of the modifications of which is spontaneously inflammable, as are some forms of phosphoretted hydrogen. Silicide of calcium is unavoidably found at times when ferro-silicon is manufactured in the same furnace as has been used for the manufacture of calcium carbide. Appreciable masses of this body are often present in commercial calcium carbide, and under the action of acid it instantly yields spontaneously inflammable siliciuretted hydrogen. There would be nothing surprising in the fact that a similar reaction might occur under the action of water, and even more readily under the action of a sea water. The results derived from the tests and analyses were hardly convincing, as this calcium silicide is not equally distributed throughout the mass. A batch of ferro-silicon, made immediately after a calcium carbide charge, would probably be contaminated.

Captain M. B. LLOYD, in reply, said that in regard to the technical points which had been raised, he was little more than a compiler of the paper, the materials of which had been furnished by others. Unfortunately his collaborateur, Dr. Dupré, was unable to be present. With regard to the disintegration

\* Mr. Harbord writes that since the meeting he had placed some of the samples in water, and although no gas was given off during the first twenty-four hours, it then began to come off steadily, and up to the date of writing, twelve days after the date of the meeting, the sample was still giving off gas. This confirmed the results recorded by the authors.

theory which Mr. Watson Grey had brought forward, he could only say that in the samples which they had had under observation under water the disintegration did not appear to have gone any further, that these samples were comparatively fine when placed under water and their appearance had not as yet appreciably altered; they had not broken up into a fine powder in any way. With regard to Professor Le Chatelier's idea of its having been caused by siliciuretted hydrogen, it was difficult to account for that in view of the small proportion of calcium which was found to be present, and also from the fact that in none of the experiments which had been carried out, so far as he was aware, had siliciuretted hydrogen been found in the gas. However, as was pointed out in the paper, the actual nature of the gas was not so much of importance in determining the cause as the mere fact of its being inflammable and easily ignited.

The PRESIDENT'S motion that a vote of thanks be given to the authors of this paper, with special regard to the value which the Institute placed upon the appearance of a government official, who had been kind enough to come to them upon such an occasion, was carried by acclamation.

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### *CORRESPONDENCE.*

Mr. JOHN PARRY (Ebbw Vale), writes: I have read the paper and the comments thereon, and after careful consideration I am quite in accord with Professor Le Chatelier, that 0.06 phosphorus would not furnish sufficient phosphoretted hydrogen as asserted. Spontaneously inflammable siliciuretted hydrogen, as noted by Professor Le Chatelier, affords a satisfactory solution of the cause of explosion. A 59 per cent. silicon would readily oxidise with consequent increase of heat.



## THE MANUFACTURE OF PIG IRON FROM BRIQUETTES AT HERRÄNG.

BY PROFESSOR HENRY LOUIS, M.A., ASSOC. R.S.M. (NEWCASTLE-ON-TYNE).

THE Herräng Mining property, now owned by the Herrängs Grufaktiebolag of Stockholm, is situated on the Baltic coast of Sweden, some sixty miles north of Stockholm, and thus about thirty miles eastwards from the famous Dannemora Mines. The property is about eleven miles by road from Häfverö Sund, the terminus of a narrow-gauge railway line starting from Stockholm, and some sixty miles in length; it has a sea frontage of about two miles, being protected from the direct action of the Baltic by a chain of islets, which help to form an excellent harbourage for vessels drawing up to 20 feet of water. It is thus accessible by sea for some nine months of the year, the Baltic, inside of the islands, being usually frozen over for two or three months in the winter. The property comprises about 1000 acres of gently undulating, park-like land, for the most part lightly wooded with birch and oak. Over a considerable part of this property, a plan of which will be found in Plate I., are scattered numerous deposits of magnetic iron ore, which are the objects of exploitation by the Herrängs Grufaktiebolag.

Geologically the entire district consists of crystalline Archæan rocks, mainly granulite (felsitic type) and granulite-gneiss, associated with granites of apparently more recent age, and traversed by dykes of greenstone; the general strike of the rocks is WNW.—ESE., and their dip is to the northwards at steep angles, ranging mostly from 70 to 80 degrees. It will be noted that the general geological features resemble those of the Dannemora ore-field, with the deposits of which those at Herräng have also much in common. The ore deposits consist of somewhat irregular lenticular masses of magnetite, surrounded by those well-known zones or aureoles of altered rock characterised by such minerals as garnet, epidote, hornblende, &c., to which Swedish geologists give the name of *skarn*, a convenient term that well deserves introduction into our own literature of ore deposits. As is usual in such

cases, the compact massive magnetite, of which the central portion of the ore deposits consists, gradually shades off into the skarn, which is highly impregnated with magnetite at first, but gradually gets poorer as it merges into the country rock. The ore deposits are developed along a belt some 800 yards wide, traversing the property in the general direction of strike, and are usually near the junction of the greenstone and the gneissose rocks; their dip and strike are parallel to those of the general stratification. They are for the most part small, the greatest length of any one of them being about 180 feet, and the maximum width 90 feet; at least one of them has been followed down to a depth of over 300 feet. They lie very close together in many cases, and their individual small size is to a great extent counter-balanced by their very large number. Some two hundred separate deposits have been worked, and the existence of many more has been proved by magnetometric measurements. The total available area of ore in the larger mines has been estimated to exceed 65,000 square feet, or rather less than half that of the Dannemora mines. The ore consists of a somewhat granular magnetite with numerous accessory minerals, the most important of which are: iron pyrites, copper pyrites, zinc blende, galena, and, rarely, magnetic pyrites; of course the various minerals met with in the skarn also occur more or less abundantly distributed throughout the mass of the ore. Near the surface the ore is practically free from the sulphuretted minerals, but their proportion appears to increase rapidly as depth is attained. By careful hand-sorting a very high-class ore can be produced, as shown in the subjoined table of analyses (see Appendix I.), but it may fairly be said that the ore as mined contains about 35 to 40 per cent. of metallic iron existing as magnetite, and 1 to 1·5 per cent. of sulphur. The phosphorus, as in all deposits of this type, is low, though rather variable; it is usually under 0·01 per cent., and rarely exceeds 0·005 per cent.

These mines have been known from very ancient times, their first mention appearing to date back to the year 1574. Mining seems to have been carried on in a desultory fashion for some centuries, mainly by the fishermen and peasant inhabitants of the district, who sold their ores to the owners of neighbouring

blast-furnaces. There was a furnace either upon or close to the Herräng estate, and another is still working near by at Schebo. Apparently the fact that the ore became more impure in depth, and the difficulty of coping with the water, which, though really insignificant in amount, may well have proved troublesome in the absence of systematic mining or of any mining machinery, caused the gradual abandonment of most of the mines. Since the year 1833, in which regular returns were first made to the mining authorities, it would seem that now one and now another of these mines was being worked on a small scale, producing, say, 500 to 1000 tons yearly, until all work was stopped in 1878, owing to the low price of ore. In 1889 a company was formed in Stockholm, which acquired the property and the mining rights now transferred to the present company. Very little was done up to the year 1896, when mining operations were actively resumed; small parcels of the first-class ore were sold, chiefly to Germany, but it soon became apparent that the relatively small proportion of this and the cost of hand-sorting would prove fatal to the economic success of the mines. Experiments were accordingly commenced upon crushing and concentration, and as the outcome of these experiments, a plant, consisting of rock-breaker, crushing-rolls, and Monarch magnetic separators, was erected. This plant did not, however, fulfil the expectations of the owners, and the company having come to the end of its resources, operations were suspended about the end of 1898. The writer was first connected with this mining property about the beginning of 1899, and ultimately the present company was formed to carry out a scheme of operations which was proposed by him, and the execution of which was rendered possible by the very ingenious inventions of Mr. Gustaf Gröndal, under whose direct supervision the various works have moreover been erected and successfully started in the beginning of the present year.

Briefly this scheme of operations is as follows: The ore as mined is conveyed from the various mines by aerial wire ropeways to the crushing works, where it is broken and crushed wet; the pulp thus produced runs to the magnetic concentrators, which take out the magnetite; the latter is conveyed by a small aerial ropeway to the briquetting-house, where it is stamped into

briquettes, which pass next through the briquetting-furnace in which they are burnt; they are then hoisted up to the top of a pair of charcoal-furnaces, where they are smelted for high-class pig iron; the waste gases from the blast-furnace fire the briquetting-furnaces, and supply gas-engines which furnish the blast and also drive the dynamos of a central electrical station, from which power is conveyed to the concentrating works, as well as to the various mines for hoisting, pumping, &c.

Each one of the elements entering into the above scheme may now be considered somewhat more in detail:—

*Mines.*—At first it is proposed to work only those mines that are the most conveniently situated with reference to the concentrating works; the most important are the Kärri and the Glitter mines, lying some 300 yards apart, with an electrically driven hoisting and pumping plant serving both mines, about midway between them, and close to it the smaller Stoll mine. The two first named show together an ore area of about 10,000 square feet, and have been worked down to depths of 130 to 150 feet. In the Glitter mine a couple of diamond drill boreholes have proved the ore to continue to a depth of over 200 feet below the present floor of the mine, but there is no reason to suppose that it does not go deeper still. These two mines are connected by a wire ropeway of the Pohlig type, with standing and running ropes, which is continued to the concentrating works, a further distance of about 350 yards. Another important group of mines consists of the Jacobi and Eknaes mines, which are also to be connected by means of a similar ropeway, about 350 yards in length, with the Kärri mines, and other mines will be joined to the ropeway system as required, the gently undulating surface of the property being admirably suited to this mode of transport, which has moreover the advantage of not being liable to interruption by falls of snow. As the result of bygone mining operations, there are at present lying near most of the mines large dumps of low-grade ore and waste rock which are too sulphury and too poor to be worth smelting direct, but are quite rich enough to repay treatment by modern methods of concentration, so that the mines need only a more gradual rate of development than would otherwise be the case. The only mines now at work are accordingly the two first named, about fifty men being em-

ployed in them. The mines are at present worked open-cast, as is usual in Sweden, and the method of mining needs no comment, being on quite the ordinary system. At present hand-drilling is employed, but machine-drilling, using electrically-driven air-compressors, will probably be introduced before long. Any country rock that may be broken down with the ore is hoisted to bank and there picked out, no other attempt at sorting being made; the ore is transferred direct into the buckets of the ropeway, and thus conveyed to the concentrating works. The mines and ropeway are arranged at present for an output of 50,000 tons of crude ore per annum.

*Concentrating Works.*—In these the ore is tandem-crushed, wet pulverised, and magnetically concentrated. The general arrangement of the plant is shown in Plate II. The ropeway from the mines delivers the ore into a large hopper, whence it passes to a large crusher of the well-known Gates pattern (size No. 7), which breaks lumps of ore, as large as can be conveniently handled, down to about 2 inches cube. The product from this breaker is divided by means of shoots between two smaller (size No. 3) breakers, which reduce the ore down to about  $\frac{1}{2}$  inch cube. This breaking is done dry. The broken ore is caught in iron cars, which are hoisted by a platform hoist to the top of the building, where it is distributed to the feed-hoppers of four wet-crushing Gröndal ball-mills. The feeding arrangement consists of an ordinary roller-feeder driven at a uniform rate and capable of accurate adjustment. The mills, as shown in longitudinal section and end elevation on Plate III., consist of horizontal cylinders, 48 inches in length and 48 inches in diameter (inside measurements), built up of longitudinal steel ribs, 0.33 inch deep, with cast iron end plates, through one of which the ore is introduced together with water, escaping as pulp in a finely-ground condition through the other end plate; no screens are required. The mills are carried on rollers (not shown) and driven by pinions keyed on a long shaft and gearing with a crown wheel bolted round the middle of each cylinder. Each mill is charged with about 2 tons of balls of chilled cast iron, ranging in size from 6 inches diameter downwards. Experience in other Swedish concentrating works, where these Gröndal mills are extensively used, has shown that the wear of the balls amounts on the average to about 2 lbs.

of metal per ton of ore crushed. As the balls and other wearing parts will be cast at Herräng direct from the blast-furnace, and all scrap will be returned to it, the cost under this head will be trifling. The ball-mills make 28 revolutions per minute, require 20 to 25 horse-power each to drive them, and will grind 50 to 100 tons of ore each per 24 hours. The degree of fineness of the crushed ore is regulated by the speed of the water-current sweeping through the mill. With the present water consumption of about 10 cubic feet per minute, 80 per cent. of the ore is ground to under 0.02 inch.

The pulp passes to the magnetic separators, each consisting first of the magnetic slime-box, and secondly of the separator proper. The former is shown in longitudinal and transverse section on Plate IV. It consists of an ordinary V box receiving a stream of clear water through the pipe A, whilst the ore pulp to be treated enters at B. Between each pair of these V boxes is a horizontal electro-magnet, either pole of which terminates in a hatchet-shaped pole-piece (M), the edge of which nearly touches the level of the pulp in the box. The dimensions of the box and the velocities of the pulp and clear water currents are so arranged that everything except the finest slimes settles in the box and passes through the pipe C to the magnetic separator, the fine slimes overflowing at D, and being drawn off by the pipe E, whence they run to waste. Any magnetic matter contained in these slimes is arrested when it comes within the magnetic field produced by the wedge-shaped pole-piece, and accumulates at the surface of the water until it forms masses of such size as to drop down and be carried away through the pipe C by the issuing stream of water; the strength of the electro-magnet is such as just not to lift any of the magnet particles out of the water. The object of this simple device is thus to get rid of the bulk of the non-magnetic slimes, whilst at the same time ensuring that none of the magnetic material shall be lost; it seems in practice as if the particles of magnetite once magnetised in this way retain some magnetic polarity and have a certain tendency to cohere, and are therefore less troublesome than ordinary slimes.

The pulp freed from slime now passes to the separators proper; one of these is shown in section and front elevation (partly

sectional) on Plate V. A magnet A with pole-pieces of the same shape as those used for the slime-boxes is surrounded by a drum B composed of alternate bars of soft iron and brass. This drum rotates at 100 revolutions per minute about 1 inch above the surface of the pulp, which traverses a pyramidal box as shown, this being divided into two compartments by a partition reaching nearly up to the top of the box. The pulp enters at C, and a stream of clear water entering at D and rising up on the same side of the partition, carries all the pulp well over the edge of the latter and thus immediately under the drum. The bars of iron composing the latter become powerful magnets so long as they are within the very strong magnetic field of the pole-piece, and they therefore pick up all magnetic particles from the stream of pulp. The remainder of the pulp drops down on the other side of the partition, and is carried off by the stream of water through the aperture E into a launder, which discharges direct into the sea, the works being built close to the shore. The pure magnetite is lifted by the drum to the very edge of the magnetic field, where it is thrown off at F by the speed at which the drum revolves. The middlings, consisting of particles that are in part magnetite and in part barren rock, and containing about 55 per cent. of iron, 0·5 per cent. of sulphur, and 0·003 per cent. of phosphorus, are flung off before they reach so weak a part of the field or at about G; these are returned to the ball mills for re-crushing, and pass again to the separators with the ore pulp in the ordinary way. There are four of these two-drum separators, each with a corresponding slime-box. The capacity of this plant is fully 200 tons per twenty-four hours; the entire plant requires an electric current equal to 24 ampères at 120 volts, or say 4 horse-power, whilst less than 1 horse-power is required to drive the drums.

A dynamo capable of generating 40 ampères at 120 volts is provided, and is found to possess a considerable margin of power. Hitherto the plant has never been pushed, the best week's work so far having been 636 tons of concentrates.

The crushed ore contains about 40 per cent. of iron, 0·5 per cent. of sulphur, and 0·003 per cent. of phosphorus; and the tailings, which are practically free from magnetite, contain about 9·5 per cent. of iron, 2·5 per cent. of sulphur, and 0·0035 per

cent. of phosphorus. The following is a typical analysis of the concentrates produced :—

	Per Cent.
Fe <sub>3</sub> O <sub>4</sub> . . . . .	88.74
Fe <sub>2</sub> O <sub>3</sub> . . . . .	1.34
MnO . . . . .	0.65
MgO . . . . .	1.01
CaO . . . . .	2.30
Al <sub>2</sub> O <sub>3</sub> . . . . .	0.79
SiO <sub>2</sub> . . . . .	5.70
P <sub>2</sub> O <sub>5</sub> . . . . .	0.006
S . . . . .	0.17
Cu . . . . .	0.015
	<hr/>
	100.721
Fe . . . . .	65.20
P . . . . .	0.0026

It is easy to produce concentrates with 70 per cent. of iron, but in practice about 65 per cent. is aimed at, as this leaves enough silica and alumina in the ore to form a suitable amount of slag in the blast-furnace.

The concentrating plant requires altogether 180 gallons of water per minute; this water is pumped from the sea by means of rotary pumps delivering into a tank through a 6-inch pipe; a portion of this water is caused to circulate through the water tuyeres of the blast-furnace and the jackets of the gas-engine, and is thus kept from freezing in the winter.

The concentrating works are driven by a three-phase motor of 150 h.p., which supplies the whole of the motive power required; there is, however, a stand-by engine with its boiler in case of any accident or break-down.

*Briquetting Plant.*—The concentrates are delivered by the ropeway from the magnetic separators to a store holding about 1000 tons, where the material remains about a week, and is by that time sufficiently drained for briquetting. It is lifted by a bucket elevator to the hoppers feeding a couple of briquetting-presses. These are drop-presses, the plunger being lifted by a three-throw cam, so that each briquette receives three blows, the height of drop ranging from 6½ to 7½ inches, and the falling weight being 16 cwt. The briquettes measure 6 inches by 6 inches by 3 inches, and weigh about 10 lbs. Each press makes eight to twelve briquettes per minute, there being two presses,



each requiring 3 h.p. The briquettes are lifted one by one off the press by a couple of men, using suitable trowels, and are placed on the cars shown in Plate VI., made of iron and covered with firebrick; the surface of the car measures 40 inches wide by 80 inches long, and each takes two layers of briquettes on edge, there being 84 briquettes in each tier; thus each car holds about 15 cwt. of briquettes. The loaded cars (see Plate VII.) are transferred one by one to the long tunnel-shaped furnace shown in Plate VIII.; it is gas fired, the combustion chamber being about one-third of the length of the furnace from the intake end. All the cars are made, as shown on Plate VI., with a groove along one end and a projecting rib at the other, and as they are advanced by being pushed in, these fit gas-tight; the longer sides of the cars are fitted with a deep flange, which dips into a channel kept filled with sand, and running the full length of the furnace. The row of cars thus constitutes an air-tight horizontal partition, below which the air needed for combustion is admitted, keeping the wheels and framework of the cars cool. The wheels move in roller bearings and are lubricated with graphite, an arrangement that seems to suffer very little from the very moderate degree of heat to which it is exposed. The row of cars does not reach quite to the discharge end of the furnace, and the air current passes below the cars to that end and returns above them towards the combustion chamber, traversing the mass of burnt briquettes, cooling these and at the same time becoming itself heated. The products of combustion pass over the entering cars of briquettes as these advance towards the combustion chamber, thus heating these and becoming themselves so thoroughly cooled that they escape into the stack at a temperature of only about 150° C. The cars of burnt briquettes are drawn at about the same temperature, when a car is taken out regularly every half-hour. Owing to these applications of the regenerative principle, the thermal efficiency of the furnace is very good, the chief sources of loss of heat being the evaporation of the water contained in the raw briquette (about 7·5 per cent. of the weight of dry concentrates) and radiation from the furnace itself, the latter not being at all important. When fired with producer-gas, it was found that the consumption of coal in the producer amounted to 3·75 per cent.

of the weight of briquettes burnt. There are three of these tunnel furnaces, and their output at the above rate of working is just over 100 tons of briquettes per twenty-four hours. The three furnaces have turned out as much as 1028 tons of briquettes as their best week's work. The temperature in the combustion chamber reaches  $1300^{\circ}\text{C}$ ., and at this heat the magnetite agglutinates sufficiently to form a firm hard briquette, which will indeed stand much rougher usage than it is exposed to at Herräng.

In addition to its mechanical action, the briquetting-furnace further acts as an exceptionally efficient calciner for removing practically the whole of the sulphur; it has already been pointed out that the concentrates retain a notable proportion of sulphur, but this is almost entirely eliminated in the briquetting process, as shown by the subjoined analyses of briquettes:—

	Older Briquette. Per Cent.	Present Briquette. Per Cent.
Silica . . . . .	7.50	5.50
Ferric oxide . . . . .	86.99	85.93
Ferrous oxide . . . . .	0.55	3.96
Alumina . . . . .	0.80	0.76
Oxide of manganese . . . . .	0.70	0.63
Lime . . . . .	3.40	2.23
Magnesia . . . . .	0.20	0.97
Phosphoric acid . . . . .	0.002	0.006
Sulphur . . . . .	0.016	0.010
Copper . . . . .	...	0.007
	<hr/> 100.158	<hr/> 100.003
Metallic iron . . . . .	61.32	63.16
Phosphorus . . . . .	0.001	0.0026

It will be remembered that in Swedish charcoal blast-furnace practice, in which a slag between a bi-silicate and a sesqui-silicate is aimed at, the elimination of sulphur from the ore before smelting is very essential, as but little can be got rid of in a slag of this composition.

The gas for firing these furnaces is a portion of the waste gas of the blast-furnaces, being taken from the waste gas flue. It contains 22 per cent. of carbonic oxide and 15 per cent. of carbonic acid. In case the supply of waste gas should ever be insufficient from any cause whatever, a small battery of three gas-producers of the ordinary Siemens type, with closed ashpit

and a steam-jet blast, has been erected, and a supply of coal is kept at hand, ready for any emergency. Producer-gas has so far only been used in starting the briquetting-furnaces before the blast-furnaces were in operation. The gas from these producers can also be conveyed to the gas-engines in the power station, which is the more necessary since the blast-furnace blowing-engines are driven by these gas-engines, which need producer-gas to start them. Up to the present something like 6000 tons of briquettes have been made by this method, and are found to work quite satisfactorily in the blast-furnace.

The briquettes are removed from the cars and stacked near the delivery end of the briquetting-furnaces, close to a small Blake stone-breaker, in which they are broken into pieces of convenient size for charging into the blast-furnace. From this stone-breaker an inclined hoist takes the broken material to the charging platform of the blast-furnaces.

*Blast-Furnace Plant.*—An integral element of this plant is constituted by the charcoal stock-house, which presents several novel features. Herräng is particularly well situated for obtaining a supply of charcoal, as the bulk of the charcoal consumed in the Swedish blast-furnaces is prepared from the slabs and other offal wood at the large sawmills situated along the shores of the Northern Baltic, both in Sweden and in Finland. For the manufacture of charcoal pig iron of the highest quality, the source from which the charcoal is obtained is not a matter of indifference; a large proportion of the timber cut up in these sawmills is floated down the rivers to the mills, and lies for a twelvemonth or more in water. It has been found that a noteworthy proportion of the phosphates contained in the wood is thereby leached out, and as this operation affects more especially the outer portions of the logs, charcoal made from sawmill slabs is lower in phosphorus than that obtained from other sources. The charcoal obtained from the Baltic sawmills appears to contain on an average 0.0068 per cent. of phosphorus.

The charcoal is transported on the Baltic in large barges, carrying from 45,000 to 65,000 cubic feet of charcoal (about 220 cubic feet of charcoal weigh one ton), which are towed to their destination. At Herräng they are moored alongside of a special pier, where two barges can be unloaded simultaneously

by means of light iron buckets operated by a couple of electric hoists. The buckets, of 35 cubic feet capacity, are run by a short overhead ropeway into the charcoal stock-house, which is built on the shore close to the above-named pier; by this means about 14,000 cubic feet of charcoal can be transferred from the barges to the stock-house in a 10-hour shift. The stock-house is 750 feet long, 115 feet wide at the base, with sides sloping inwards at an angle of about 60 degrees, and 50 feet high; it is calculated to contain about  $2\frac{1}{2}$  million cubic feet of charcoal. Along the bottom of the stock-house, on either side, are loading doors from which the charcoal is loaded into buckets, which are taken to the furnace-top by means of an inclined wire ropeway.

Limestone is obtained from the quarries of the Karta and Oaxens Quarry Company, being well known in this part of Sweden for its purity. It is delivered by sea on to the wharf at Herräng, and can thus be laid down at the furnaces at a cheap rate; on account of its high quality it is used in preference to working a poorer limestone belonging to the Herräng Company. The following is an analysis of the Oaxen limestone, furnished by the quarry company:—

	Per Cent.
Lime . . . . .	53·74
Magnesia . . . . .	0·17
Ferrie oxide . . . . .	0·18
Alumina . . . . .	0·32
Sulphur . . . . .	trace
Phosphoric acid . . . . .	0·006
Silica and insoluble . . . . .	3·14
Loss on ignition . . . . .	42·42
Alkalies, undetermined, and loss . . . . .	0·024
	<hr/> 100·000

There are two blast-furnaces 47 feet 3 inches in height and 10 feet in diameter at the boshes, and have six tuyeres 1·89 inches in diameter; they have closed tops, and are fitted with the well-known Tholander cup and cone. They are protected by the substantial stone building customary in Sweden, and rendered necessary by the severity of the climate, the pig beds being similarly protected; the iron, as usual in Sweden, is run into iron moulds. The blast, equal to 6000 cubic feet per minute, is heated in a pair of Tholander pipe stoves with horizontal pipes, which maintain a blast temperature of about 450° C. Blast

at a pressure of  $2\frac{1}{2}$  lbs. per square inch is furnished by a two-cylinder blowing-engine, belt-driven, each cylinder being 48 inches in diameter and 48 inches stroke, running at thirty strokes per minute and absorbing about 75 h.p. As already stated, the furnace gases are conveyed by flues to the briquetting-furnaces and to the gas-engines of the power station, to be referred to presently, as well as to the hot-blast stoves. Each furnace has been calculated to produce 9000 tons of pig iron annually; their actual output is 25 tons per 24 hours, or rather above the calculated amount. The furnace charge consists of—

Charcoal	. . .	15 hectolitres = 530 lbs.
Briquettes	. . .	540 kilos. = 1190 „
Limestone	. . .	40 kilos. = 90 „

The charcoal consumption is thus under 14 cwt. to the ton of pig, an exceptionally low figure, whilst the output of the furnaces is exceptionally large, these advantages being obtained by the smelting of briquettes instead of ore. With so valuable a fuel as charcoal, a low fuel consumption is a point of the greatest economic importance. The low fuel consumption required for smelting briquettes is also an important element in keeping the phosphorus in the pig iron produced as low as possible, the fuel being, as already indicated, the source whence much of the phosphorus is derived. The composition of the pig iron produced is as follows:—

	Grey Pig. Per Cent.	White Pig. Per Cent.
Phosphorus . . . . .	0·012	0·009
Sulphur . . . . .	0·007	0·011
Manganese . . . . .	0·025	0·025
Silicon . . . . .	0·60	0·15

The following is the analysis of a typical slag:—

	Per Cent.
Silica . . . . .	50·86
Alumina . . . . .	2·64
Lime . . . . .	36·50
Magnesia . . . . .	6·10
Ferrous oxide . . . . .	1·55
Manganese oxide . . . . .	1·81
Phosphoric acid . . . . .	0·022
Sulphur . . . . .	0·308
	<hr/> 99·790

It will be seen that this is a typical bisilicate slag.

*Power Station.*—This is a substantial stone building containing the gas-engines, dynamos, and blowing-engines. There are two gas-engines of the Deutz double-acting four-cycle type, each capable of giving out 200 i.h.p., and consuming about 100 cubic feet of gas of the composition already given per hour and horsepower. The two engines require per hour about 1000 cubic feet of cooling water, which they heat to about 70° C. The use to which this heated water is put has already been mentioned. These engines drive a long main shaft from which the blowing-engines above described are driven by means of belting; a pair of three-phase 50-period electric generators, delivering current at 800 volts, and absorbing 175 h.p. each, are also driven off the main shaft, as also are a pair of small continuous current dynamos used as exciters and for electric lighting, a small air compressor, pumps, &c. The concentrating and briquetting plants have been in operation for some time, but the blast-furnaces were only blown in early this year, and have since continued to work quite satisfactorily.

Although the Herräng works are only upon a small scale, yet the author ventures to submit that they embody several principles, the importance of which has only recently been recognised, but which appear nevertheless destined to play an important part in the metallurgy of iron in the near future. In the first place, the principle, long ago recognised in the metallurgy of most other metals, that injurious impurities should be eliminated from the ores at the earliest possible moment, is here successfully applied to iron-smelting, resulting in the production of a high-class pig iron from an ore containing very serious amounts of that troublesome impurity, sulphur, which is here eliminated before the ore goes into the furnace instead of being got rid of at a later stage. Secondly, the possibility of the successful removal of impurities by mechanical means is here illustrated. Hitherto the elimination of the impurities of iron ores—mainly silica, sulphur, and phosphorus—has generally been performed by chemical means, this removal being to a great extent conducted simultaneously with the smelting operation proper, or the reduction of the oxide of iron to the metallic state. It can of course only be applied to those ores which contain their impurities in a

state of mechanical admixture, and is useless for those in which the impurities are chemically combined with the oxide of iron. Even in cases where such removal of impurities is technically possible or even advantageous, it does not always follow that it must be the commercially superior method; seeing, however, that chemical elimination can only be performed at the expense of fuel in the blast-furnace, and that the tendency of the price of fuel suitable for blast-furnace purposes is to rise, whilst in this country, at any rate, it has steadily been deteriorating in quality, and that, at the same time, improvements in the generation of power enable mechanical methods to be cheapened, it may fairly be inferred that the mechanical elimination of impurities is likely to be more advantageous economically in the future than it has been in the past. Lastly, Herräng affords one of the first examples of the employment of power, generated from the waste gases of the blast-furnace, for the purpose of mining the ore smelted in that furnace. This principle appears to be economically quite sound, and its extended application may ultimately result in a re-shifting of the centres of the iron industry; originally, of course, these were situated in iron-mining regions, and were gradually removed to the coalfields, as fossil fuel took the place of charcoal, and as the use of coal in working up the crude products of iron smelting assumed greater importance, until to-day the great centres of iron manufacture are everywhere situated upon or close to important coalfields. If, however, it is found that power, which may fairly be considered as one of the by-products of iron smelting, can be advantageously utilised in mining iron ore, there would appear to be at any rate a possibility that smelting works may in some cases return to the ore-producing regions, and that it may once again be found to be more economical to take the fuel to the ore, the former acting now in the double capacity of source of power as well as smelting agent.

APPENDIX.—*Analyses of Hand-picked Ores.*

	Glitter Mine.	Kärr Mine.	Kärr Mine.	Eknaes Mine.	Mark- dals Mine.	Nyby Mine.	Rya Mine.	Adolfs Mine.
FeO. . .	74·38	71·27	82·03	82·03	82·85	93·22	75·80	77·80
FeO. . .	1·70	3·71	2·71	5·16	1·30	...	2·71	0·27
MnO. . .	0·69	0·65	0·45	0·45	0·24	0·38	0·34	0·11
CaO. . .	6·45	6·65	2·70	2·02	1·25	0·85	3·15	2·36
MgO. . .	3·13	3·27	2·21	2·19	2·03	0·60	4·23	0·62
AlO. . .	0·85	0·33	0·78	1·00	0·80	0·75	0·50	1·18
SiO. . .	12·55	13·55	8·60	7·20	11·40	3·60	13·15	17·00
PO. . .	0·009	0·006	0·002	0·005	0·007	0·016	0·004	0·021
S. . .	0·3000	0·308	0·354	0·149	0·010	0·317	0·014	0·030
Total .	100·059	99·744	99·836	100·204	99·887	99·733	99·898	99·391
Fe . . .	55·17	54·20	61·81	65·60	63·00	60·90	67·50	56·80
P . . .	0·004	0·003	0·001	0·002	0·003	0·007	0·002	0·009



*DISCUSSION.*

Mr. A. P. HEAD (London) thought the Institute ought to be very much obliged to Professor Louis for the very interesting way in which he had brought this plant before their notice. He had visited the spot in July last, and was very much interested in what he saw, and especially by the ingenuity of the ball crusher and by the magnetic separation, involving the combined action of the slime-box and the separator proper. There was one point about the location of those works which perhaps Professor Louis had hardly taken full credit for, and that was the situation on the sea coast. Professor Louis spoke about the blast-furnace going back to the iron mines instead of being on the fuel supply. It seemed to him, from what he had seen of the Swedish iron industry, that it was the waterfalls, rather than fuel or ore, which had settled in the past the position of the blast-furnace. One had only to think of the number of times in which the word "fors," which meant "waterfall," occurred in the names of Swedish ironworks to see how important the possession of a waterfall for power purposes was considered when they were founded. Having once been started it was not an easy matter to alter the position of the ironworks. Therefore, as a rule, they found in Sweden that blast-furnaces were located primarily near a waterfall, also as near as possible to the iron ore, and, if possible, near timber forests where charcoal could be obtained. Very little attention seems to have been paid to means of communication with the outer world. He knew of no works so well situated as those at Herräng for water transport, which gave them great advantage in the way of getting cheap charcoal, and tapping the whole charcoal market, since the source of supply was very largely the saw-mills and timber-shipping points on both shores of the Baltic Sea and the Gulf of Bothnia. It frequently happened in the case of the older works that they quickly cut down all the timber, and had to go further and further afield until cost of transport became prohibitive. The Herräng works could never be in that position; they could always get the best charcoal at the best prices, and incidentally

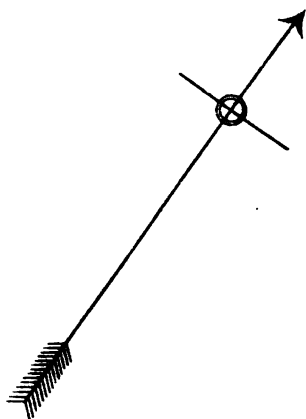


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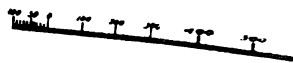
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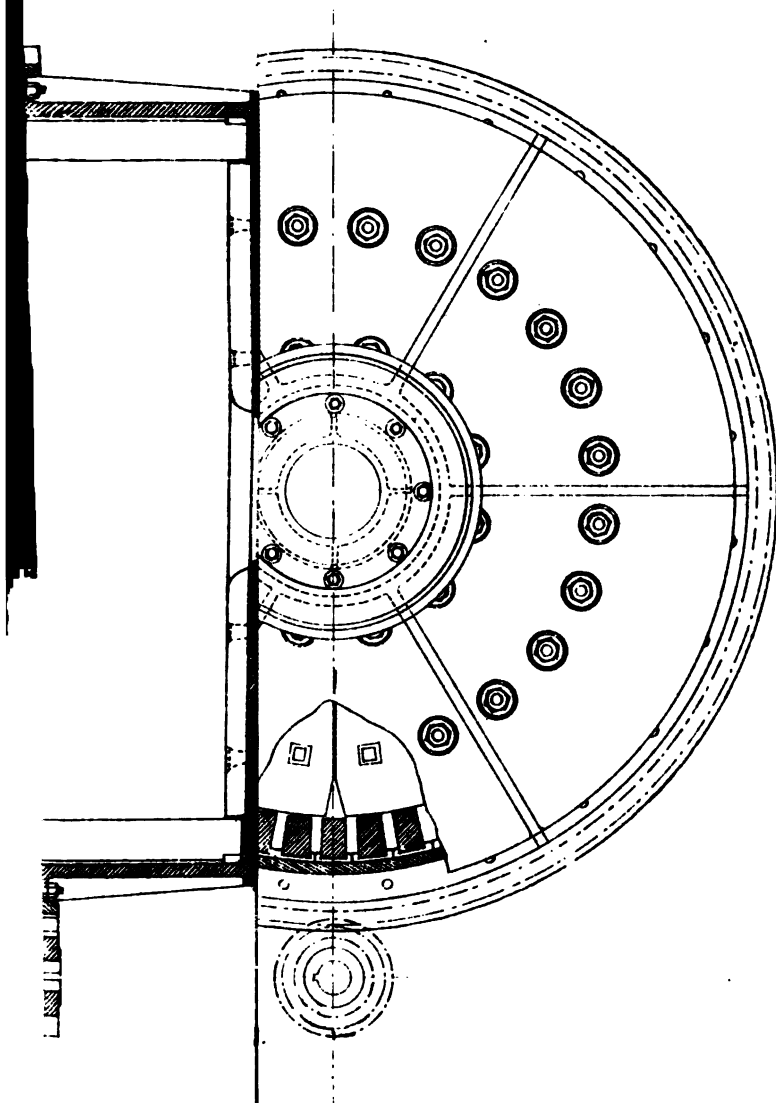
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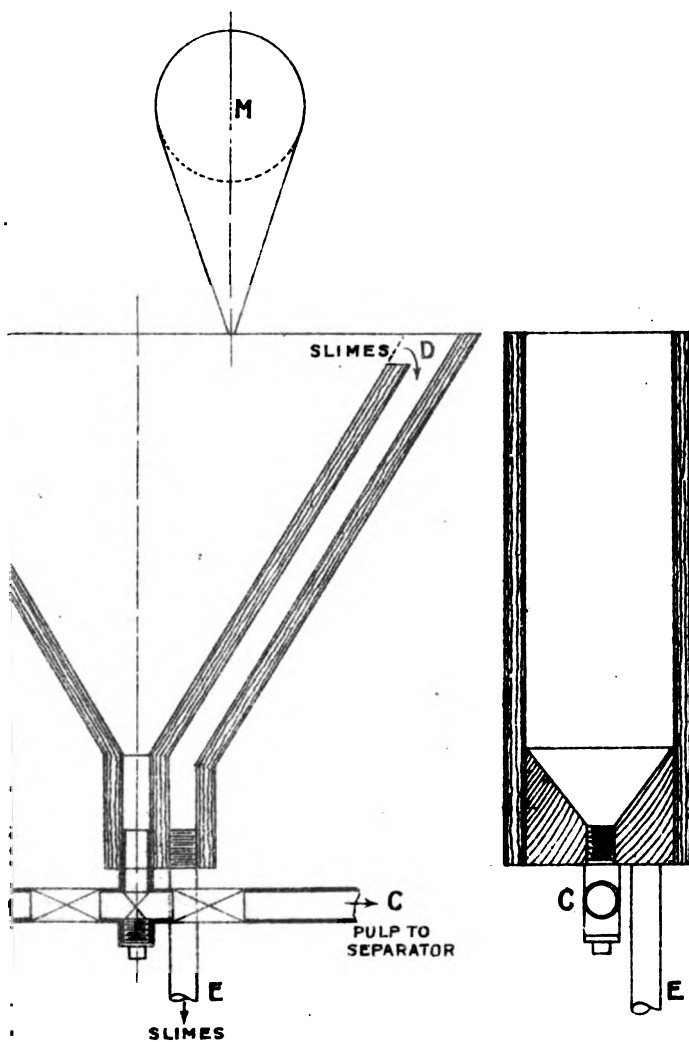
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# MAGNETIC SLIME BOX.

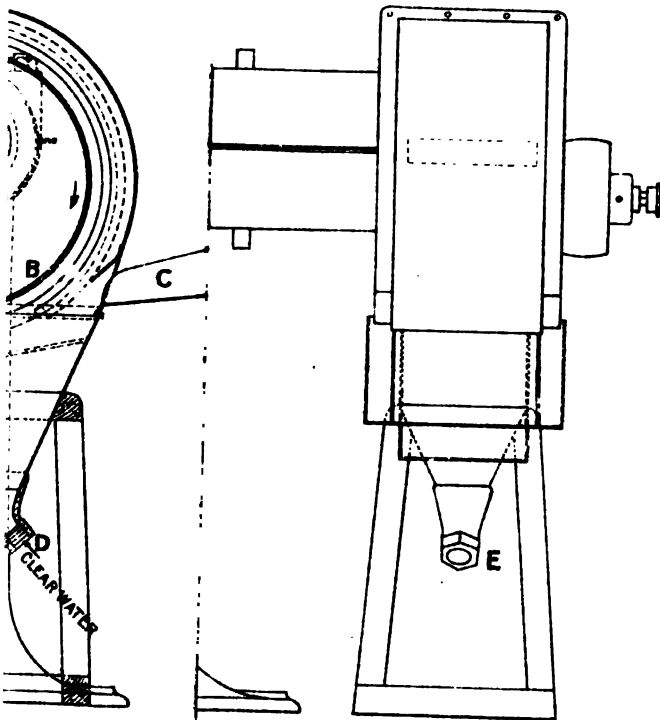
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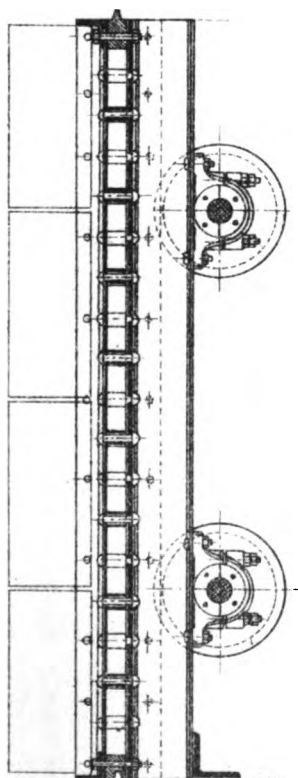
TION.

N SECTION.

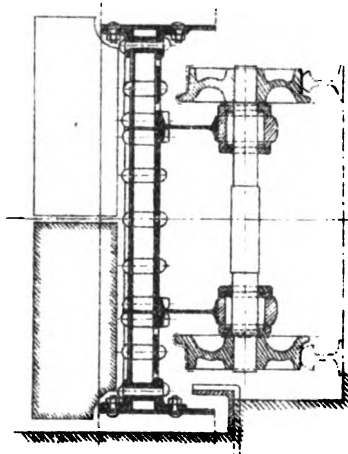
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# BRIQUETTING-FURNACE CAR.

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LONGITUDINAL SECTION.



CROSS SECTION.



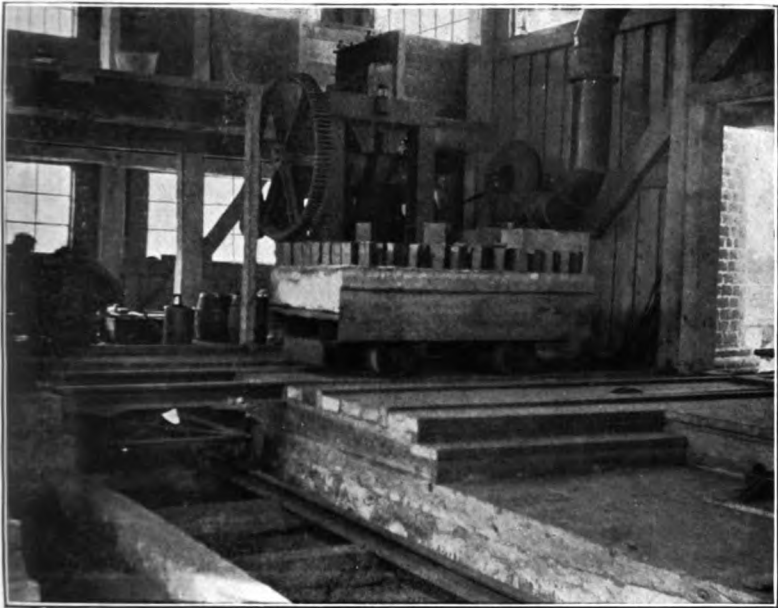


FIG. 1.—Car with briquettes.

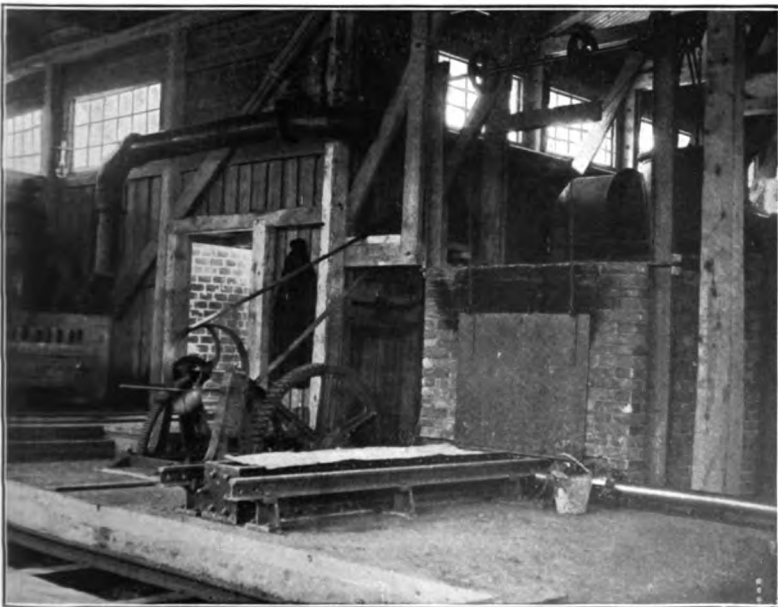


FIG. 2.—Briquetting furnace, from charging end.

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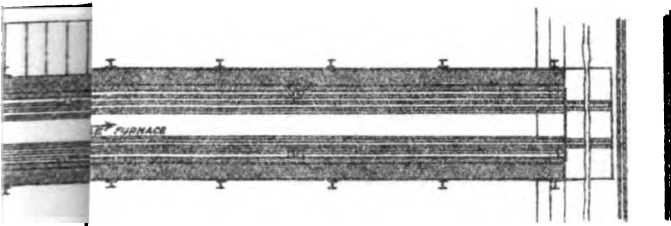
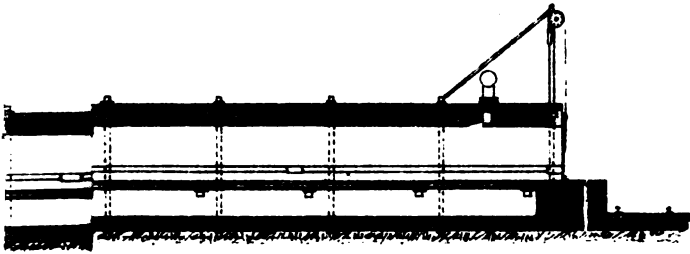
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## BRICK-MAKING FURNACE.

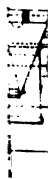
FIREBRICK SHOWN THUS



COMMON BRICK SHOWN THUS

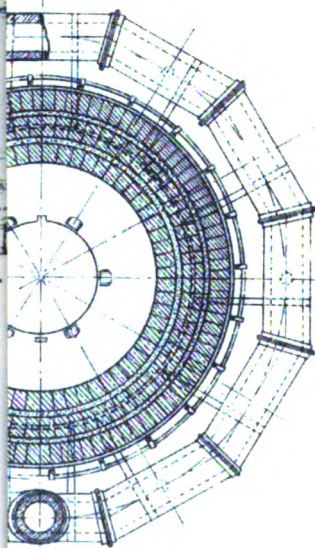




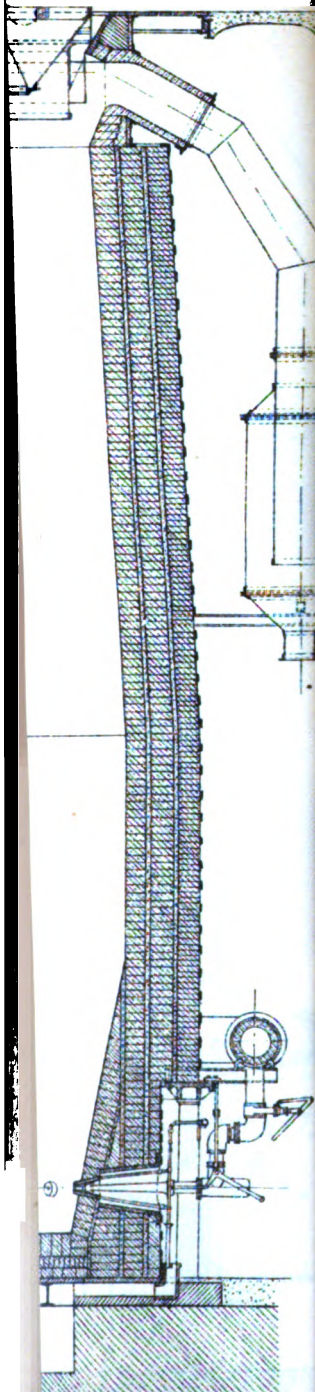


AT HERRÄNG.

=  $\frac{1}{100}$ .



VERTICAL SECTION  
WITH THE BOSHES





they had their iron mines close at hand. Therefore he thought there ought to be a very good future before these works, and they ought to be able to compete successfully with the existing Swedish works in the production of that high-class material for which Sweden was famous.

Dr. WEISKOPF (Hanover) said that for more than ten years attempts had been made to utilise those iron ores which, owing to their high percentage of insoluble residue, or owing to the presence of deleterious constituents, such as phosphorus, sulphur, copper, arsenic, zinc, titanium, &c., were regarded as unsuitable for blast-furnace use. All the methods hitherto employed for separating the valuable portion had proved, with so cheap a raw material as iron ore must be, far too costly, and the difficulty of concentrating and briquetting was not in the technical carrying out, but in the cost. In Professor Louis' exhaustive paper he missed altogether details of the cost of the various operations, such as: What was the cost of crude ore? What was the cost of concentration? What was the loss of weight, and of iron caused thereby? What was the cost of briquetting? He had not the slightest doubt as to the practical possibility of the method described, but as he had had personal experience of the working of the Gröndal concentrating and briquetting process, he could not help coming to the conclusion that, from an economic point of view, it was not possible to obtain favourable results, the Gröndal briquetting plants formerly in use having been abandoned owing to their cost and untrustworthiness. He should be glad to know if the author would favour them with information on these points.

Professor H. BAUERMAN (London) said he had read the paper with great interest, and the more so as it was in that part of Sweden, or rather in a district a little to the south of that described in the paper, that he had in 1864 made his first acquaintance with the masses of magnetic iron ores in the older rock formations of the world. At that date he was engaged in a plan for shipping Swedish iron ores to the north-east of England, which was carried out, but only for a short time. It was, in fact, about thirty years too early. The Herräng group was proposed

among the sources of supply, but excluded on account of the sulphur, apart from which the minerals were of excellent quality. He was glad therefore to see that the principal difficulty in the way of their utilisation had been got over by the very ingenious arrangements described by Professor Louis. The complete peroxidation of the ore during the consolidation of the briquettes he supposed was due to the action of a very free supply of air to the kiln during the slow progress of the cars containing the briquettes, 145 feet in 24 hours. In the vertical Swedish kiln heated with blast-furnace gas the lumps of ore did not seem to be so completely changed, being cracked and fissured, but otherwise retaining their original form. Perhaps the residual silicates in the concentrated mineral might have something to do with the consolidation. These are easily fusible silicates, and might help in the binding, but whatever might be the cause, the result seemed to be one which had succeeded perfectly.

Professor HENRY LOUIS in reply said he would like to point out to Professor Bauerman that the rate at which the ore passed through the horizontal briquetting furnace was made especially slow in this particular case in order to get a complete elimination of the sulphur. The essential point in economic smelting in a charcoal blast-furnace was to have an easily fusible bisilicate slag which would not, however, take up much sulphur. Desulphurisation being the essential point, the rate at which the briquettes passed through the furnace was determined, not by the speed of briquetting, but by that of desulphurising. He had worked that furnace at a much greater rate, over three times as fast as it was being worked in practice, when he was experimentally briquetting ores which were free from sulphur, and the result had been perfectly satisfactory so far as the briquetting was concerned, when desulphurising was not a question to be considered. He did not think that Professor Bauerman's suggestion of the easily fusible silicates in the ore helping the action was correct, because he had experimented with a very great range of ores, and had briquetted ores containing over 70 per cent. of metallic iron where the amount of silica present was practically *nil*. As far as his experiments went, oxides of iron

appeared to soften and to agglutinate at temperatures somewhere about  $1300^{\circ}\text{C}.$ ; say between  $1250^{\circ}\text{C}.$  and  $1350^{\circ}\text{C}.$  or  $1400^{\circ}\text{C}.$  one got agglutination of the oxide of iron itself. He had not any doubt in his own mind that it was that agglutination and not the presence of those fusible silicates that had to do with making the strong briquette which was submitted to the meeting. He was much obliged to Mr. Head for his remarks. The natural consequence that, as waste blast-furnace gases were more and more utilised, water-power would become of less importance, seemed of course obvious enough. With regard to Dr. Weiskopf's remarks, he had carefully avoided saying anything about cost, because he understood that the purely economic aspect was not one which was a fit subject for discussion at that Institute. But at the same time he thought he might be allowed to say that he would never have recommended the erection of that plant and the adoption of that method unless he had been convinced that it could be worked with a very decent margin of profit. He presumed that members present who had had experience in general mining and smelting operations would be able to form a very fair opinion for themselves as to what that margin was likely to be when they bore in mind that the Herrång works were practically getting the whole of their power and fuel for briquetting as a waste product. He might perhaps be allowed to add that the result since the works had been started had fully borne out his anticipations regarding economic working. Mr. Hanson would find at any rate a partial reply to his question in the paper itself.

The vote of thanks moved by the PRESIDENT to the author for his interesting paper was carried by acclamation.

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### CORRESPONDENCE

Mr. WELDON HANSON (Stockton-on-Tees) pointed out that it would add very much to the value of Professor Louis' excellent paper if he could give an analysis of the gases escaping from the charcoal furnace when using 14 cwts. charcoal per ton iron.

Mr. J. E. STEAD, Member of Council, wrote to say that by permission of Professor Louis he had since analysed the samples exhibited at the meeting. These consisted of the crude iron ore, concentrated iron ore, refuse, briquette, and the metal made from the briquette.

The following are the results obtained, viz. :—

	Iron per Cent.	Sulphur per Cent.	Phosphorus per Cent.
Crude iron ore . . . . .	39·30	1·13	0·006
Concentrated iron ore . . . . .	62·90	0·27	0·003
Refuse . . . . .	11·40	1·58	0·017

*Analysis of Briquette.*

	Per Cent.
Iron . . . . .	61·10
Silica . . . . .	8·50
Sulphur . . . . .	0·008
Phosphorus . . . . .	0·003

*Analysis of Pig Iron.*

	Per Cent.
Manganese . . . . .	0·113
Silicon . . . . .	0·270
Sulphur . . . . .	0·005
Phosphorus . . . . .	0·012
Copper . . . . .	0·030
Arsenic . . . . .	nil

It will be observed that the results practically confirm the Swedish analyses, and that the pig produced from the briquette is peculiar in having a very small content of sulphur, although the original ore from which it was produced contained 1·12 per cent. of sulphur.

The briquette is excellent in every respect. It is hard, porous, and in a most suitable condition for smelting in the blast-furnace.

## NOTES ON THE PRODUCTION AND THERMAL TREATMENT OF STEEL IN LARGE MASSES.

BY COSMO JOHNS (SHEFFIELD).

A NUMBER of interesting papers have been read before this Institute during the last few years, dealing with the thermal treatment of steel, the great value of which the author hastens to acknowledge: the result of the vast extent of research work thus made public has laid the steel manufacturer under a deep obligation. With a few exceptions, however, these researches have been made on a small scale. The author does not complain of this, but admits that they must of necessity have been so, having regard to the conditions under which they were made. He, however, ventures to point out that the conditions in a large works, where the thermal treatment of steel is made a speciality, are very different from those that govern laboratory experiments, and it is the extent and importance of these differences that he desires to emphasise.

First of all, the mass of the steel that happens to be under treatment plays a most important part, for heat takes an appreciable time in its transmission through the mass. Now, in a small laboratory specimen the mass plays a very insignificant part, the element of time is reduced almost to zero, and such terms as "rapidly heating," "cooling quickly in air," have a very definite meaning. It so happens, however, that the steel products, in whose manufacture heat treatment plays a part, are all of considerable size. For instance, a railway axle weighing 500 lbs. offers a mass that is out of all proportion to the small specimens often experimented upon, and yet axles are about the smallest of the steel products of the works whose methods the author is about to describe briefly.

From an axle weighing 500 lbs. to a marine shaft 26½ inches external diameter and 86 feet in length is a stride that at once calls attention to the new conditions imposed. To ensure the homogeneity of a mass of steel like this is a problem of itself, having regard to the effect segregation of the elements plays in



even moderate masses of steel; while to heat equally to a predetermined temperature, and then to cool it at a certain rate, are operations that tax the resources of the metallurgical engineer.

Yet these, after all, are comparatively favourable examples. Certain steels are fairly easy to work and to treat in small masses, but when the mass is increased it becomes very difficult. Any attempt to heat or cool them rapidly would result in external or internal fractures. Take, for instance, a carbon steel containing 0.60 per cent. carbon; in attempting to forge a shaft, say, from a 40-ton ingot, the variation of temperature during the forging would induce stresses in the interior that in all probability would result in internal fractures with disastrous results when the shaft was used. Even with much lower carbon steels the same difficulties are met with, though to a less degree, and the mere heating or cooling of large masses of steel, 40 to 100 tons in weight, is a very delicate operation. Any attempt to accelerate the heating would cause the exterior to expand faster than the interior, and thus cause an internal fracture. A similar attempt to hasten the cooling would cause the exterior to cool faster than the interior—resulting in fracture again. But there are alloy steels even still more difficult to work. When large masses of these are treated, they have to be kept in a heated condition until worked into their final form, and even then losses through fracture or “clinks” are not uncommon.

Then, again, time is a very important factor in thermal treatment. If a small laboratory specimen and a large forging be subjected to the same treatment the resulting structure will be very different, even though the small specimen had been originally a part of the forging and was thus of the same composition.

The explanation is clear. Suppose that both had to be heated to 1650° F. and dipped in oil, the cooling would be very rapid in the case of the small specimen, but in the case of the large forging the exterior would be quickly cooled, while the transmission of heat to the cooled exterior from the still heated interior would continue to take place for a considerable time. If the cooling were done in air the same difference would arise, and what was accomplished in minutes in one case would

take days in the second. It is well, therefore, that this question of "mass" should be clearly recognised. One of the first lessons learnt in works practice is, that a course of heat treatment eminently suitable for a small specimen as determined in the works laboratory requires to be carefully revised, and the new factors of "mass" and "time" allowed for, before satisfactory results are obtained with large masses.

But "mass" and "time" are not the only elements that serve to differentiate works from laboratory practice. The manufacturer generally has to work to a specification, with rigid chemical and physical limits for his product. The author prefers not to enter into the vexed question of the expediency of these limits. The fact remains, that the specification has a very real existence and must be followed, but it also means that it limits the results that have to be aimed at and it is not always the ideal that is attained.

To "mass" and "time," therefore, must be added the "specification," and then we have the chief differences between the problem that presents itself in the works and the results of patient laboratory experiments.

The author proposes to describe briefly the practice of the works with which he is connected, and hopes it will serve as a modest supplement to the many excellent, but more theoretical papers to which he has referred.

At the River Don Works, Sheffield, of Messrs. Vickers, Sons, & Maxim, Ltd., are manufactured railway material, such as tires, cast steel crossings, crank and straight axles, &c., marine shafting, forgings and castings for engine parts, finished guns up to the largest size, forgings for gun mountings, projectiles, armour plates, &c., special blooms, billets, bars, &c., of carbon and alloy steels, thus furnishing a varied series of products, the majority of which receive thermal treatment, in one form or another. In the case of projectiles and armour plates the author is not at liberty to describe the methods by which the results are obtained, as the processes are secret ones. Steel castings are also among the products which he does not propose discussing in this paper.

Before going any further the author would describe briefly the method of manufacture of the products to be discussed later.

*Melting.*—All the steel produced at the River Don Works, with the exception of a relatively small portion made by the crucible process, is made in acid-lined open-hearth furnaces. It has been found that high-class steels, such as those referred to in this paper, used for the manufacture of guns, heavy shaftings, tires, axles, &c., can only be produced satisfactorily by the acid open-hearth process. The chemical purity, by which the author means a low percentage of phosphorus and sulphur, is secured by the careful selection of the materials used. No difficulty is found in obtaining a product under 0.035 phosphorus and sulphur. The object aimed at is to reproduce in the bath as nearly as possible the condition found in "well killed" crucible steel ready for teeming. The addition of aluminium, silicon, and other deoxidisers to the ladle is but an indifferent substitute for good melting. Steel made by the basic process would be quite unsuitable for the manufacture of the products referred to in this paper.

*Casting.*—The steel is cast in ingot moulds of circular, octagonal, rectangular, or square forms, depending upon the purpose for which the ingot is required. Circular moulds are rarely used, and then only when the ingots are comparatively short.

The moulds are made of cast iron, with an upper portion of non-conducting material, designed so that the body of the ingot may solidify and be fed by the still liquid head. This head, being the last portion to solidify, serves to include the region of segregation, with the result that the top and bottom of the body of the ingots show very little variation in composition. If the entire mould were lined with non-conducting material many of the difficulties encountered in making large ingots in chilled moulds would be removed, but there would be the objection that the ingot would solidify more equally over its mass, contraction cavities might be formed in the portion destined for use, while the region of segregation would probably occur there also.

Needless to say, fluid compression is not used. It may seem late in the day to urge objections against the idea, but as in one or two quarters there remains a tendency to see some value in the process, it might be as well to state again the chief objections.

Properly melted steel of the carbon used for products described

in this paper contracts in volume when cooling, and, even after the exterior solidifies, the liquid interior still keeps contracting, and on solidification forms internal cavities called pipes. If the ingot mould be properly designed this piping occurs in the head, leaving the body of the ingot quite solid. There will be no blowholes in the body of an ingot made of properly-melted steel of the class we are describing. If there are any, that particular ingot is unfit for use in high-class work, for the walls of the blowholes would not be welded together at the usual forging or rolling temperature. In dead soft steel there does not seem to be the same objection. An ingot free from blowholes is the proof that the steel was properly melted. We have just seen, however, that if the head of the ingot be properly designed, so that it remains liquid longer than the body, it will contain the region of segregation and also the piping. It may now be asked, Of what possible benefit can fluid compression be to properly melted steel? There are no blowholes to be reduced in volume. The pipe is already in a harmless position, while the volume of the head cannot be reduced without danger of the body of the ingot containing the segregated impurities.

The liquid steel itself cannot be reduced in volume by any practicable pressure any more than water can. The specific gravity of "fluid compressed" steel and *well-melted* steel cast in properly designed open moulds is exactly the same. Of course "fluid compression" might serve to mask some of the defects of steel that had been badly melted, by diminishing the volume of the blowholes, but in that case the correct thing would be to scrap the ingot. Fluid compression, therefore, cannot possibly be beneficial to properly melted steel.

*Forging and Rolling.*—The author does not intend to describe here the details of the forge and mill. He is not aware that they differ materially from the usual practice. It might be mentioned, however, that the correct temperature at which the steel is to be worked in the different departments is secured by the use of pyrometers whenever it appears necessary. The necessary data required for the correct treatment of the steel is supplied by a properly equipped metallurgical laboratory, where micro tests are made, cooling curves and critical points worked out, and photomicrographs made. In the chemical laboratory complete

analyses are made of every cast of steel made. The carbons are determined by the colour and combustion methods. As a rule the two methods give very near results. In the testing department the static tests are made on a hundred ton machine, while vibratory tests are made on a specially designed duplex vibratory testing machine. Working with the quality steels made at the River Don works, the results given by the static test are found perfectly reliable, and the vibratory tests have only served to confirm that opinion. The various plants for the heat treatment of the steel are capable of dealing with masses 100 feet in length and 100 tons in weight. Having thus briefly reviewed the equipment and methods of manufacture adopted, a description of a few typical products may be interesting.

*Tires.*—High-class tires form one of the special products of the works. The distinguishing feature is that they receive no treatment after leaving the rolls of the tire mill. Whatever structure may be developed must be attributed to careful supervision during manufacture. Great importance is attached to the purity of the materials used, and the steel on analysis must not show more than 0·035 phosphorus or of sulphur. The steel used is regular in composition, and care is taken that at all stages the work is done on it at the temperature that has been found to give the best results. The tires are allowed to cool in the air after leaving the rolls, and receive no further heat treatment. It is

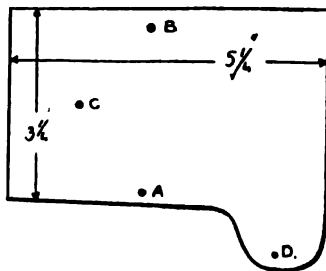


FIG. 1.—See Plate XII.

considered that, as tires have to be heated when they reach their destination, it would not be prudent to subject them at the works to a course of heat treatment that would possibly be undone when they were being fitted up for use. It will be seen from Plate XII. that the tires, though allowed to cool naturally after leaving the

rolls, have a well-marked sorbitic structure, and it would be difficult to suggest a treatment that would in any way add to their wearing qualities or increase their resistance to shock. The specifications vary, but a typical one would call for 48 to 56 tons tensile, with a minimum elongation of 15 per cent. for 48 tons, and 11 per cent. for 56 tons. There is also a drop test in which a "tup" of 2240 lbs. is allowed to fall freely on the tire (which is placed on a solid metal foundation of at least 10 tons weight) from heights of 10 feet and upwards, until the deflection of the tire reaches  $\frac{1}{8}$  of the internal diameter, except when the diameter is less than 36 inches, when the deflection should be  $\frac{1}{4}$ . The tire should not fail under this test. No difficulty is experienced in meeting these demands, and failure is almost unknown. Below are given typical examples with the results obtained:—

TABLE I.—"Vickers" Tires.

Analyses.					Treat- ment.	Test.			
C.	Mn.	P.	S.	Si.		Ultimate Stress.	Elongation per Cent.	Reduction of Area.	
						Tons.	Per Cent.	Per Cent.	
56	78	029	030	179	No heat treatment.	50.8	16.0	21.9	All passed the drop test.
57	76	026	029	187		51.8	20.0	27.4	
60	74	027	031	210		54.2	14.5	16.3	
60	73	028	031	196		53.4	16.0	21.8	
52	71	026	027	215		48.2	17.0	23.0	
58	79	031	028	200		50.4	15.7	19.4	
60	80	028	031	191		53.2	14.0	17.9	
62	83	028	032	196		55.0	14.0	17.9	
61	75	029	032	187		54.2	14.0	18.1	

**Axles.**—Both the straight and cranked axles are subjected to heat treatment. As in the case of tires, stress is laid on the purity of the steel, 0.035 being the maximum for sulphur and phosphorus. The specifications vary, but a typical one would demand that a test piece to be cut from the axle used for the shock test should give a tensile strength of 32 to 37 tons, with an elastic limit of at least 55 per cent. of the ultimate strength. The elongation must not be less than 25 per cent. on 2 inches. The shock test varies with the diameter of the axle. No difficulty is experienced in meeting the tests, and the following examples will indicate some of the results obtained:—

TABLE II.—“Vickers” Axles.

Analyses.					Treatment.	Tests.			
C.	Mn.	P.	S.	Si.		Yield Point.	Ultimate Stress.	Elongation on 2".	Reduction of Area.
·32	·54	·028	·027	·096	Oil hardened at over 1650° F.	Tons.	Tons.	Per Cent.	Per Cent.
·28	·49	·028	·027	·104		20·4	37·2	29·0	46·4
·31	·51	·029	·031	·109		19·2	35·4	31·0	46·8
·29	·49	·028	·029	·096		23·0	38·2	28·5	36·4
·30	·49	·032	·028	·117		18·2	35·4	30·0	45·0
·28	·51	·027	·029	·086		21·4	36·0	33·0	53·0
·28	·51	·027	·029	·086		21·2	34·0	36·0	55·0
·28	·49	·030	·028	·113		21·0	34·8	35·0	52·0
</									

It will be noted that a relatively high elastic limit and elongation is obtained on a moderate ultimate stress with a fairly low carbon steel.

*Shafts.*—Most of the shafts, of which particulars are given below, receive no heat treatment with a view of altering their structure. They are annealed in order to relieve the strains that may be set up during forging. An interesting example is given below, where the length might have been expected to have caused variations in the results given by test pieces taken from both ends. So far from this being the case, the two ends gave almost identical results (Plate XI.). It was hollow forged from an ingot weighing 94 tons.

TABLE III.—“Vickers” Steel Shaft.

Length, 86 feet; external diameter, 26½ inches.

Position.	Analyses.					Treatment.	Tests.			
	C.	Mn.	P.	S.	Si.		Yield Point.	Ultimate Stress.	Elongation on 2".	Reduction of Area.
							Tons.	Tons.	Per Cent.	Per Cent.
Top end	·30	·66	·028	·026	·093	As forged	15·8	30·8	30·0	40·0
Bottom end	·29	·69	·027	·026	·108		15·8	31·4	31·0	44·0
Top end	...	...	...	...	...	Heated to 1000° F. cooled slowly	16·6	30·2	35·0	52·4
Bottom end	...	...	...	...	...		16·0	30·8	35·0	53·3

TABLE IV.—*Various Shafts, "Vickers" Steel.*

Analyses.					Treatment.	Tests.			
C.	Mn.	P.	S.	Si.		Yield Point.	Ultimate Stress.	Elongation on 2".	Reduction of Area.
						Tons.	Tons.	Per Cent.	Per Cent.
30	79	029	031	134	Annealed at 1000° F.	16.3	33.6	36.0	57.0
30	74	029	031	148	Annealed at 1000° F.	16.4	32.8	36.0	56.0
31	76	028	027	104	Annealed at 1100° F.	17.6	32.6	35.0	50.7
32	79	030	029	139	Annealed at 1000° F.	16.0	31.6	33.0	40.9
31	74	028	032	084	Annealed at 1000° F.	18.6	32.3	35.0	50.7
32	81	029	031	137	As forged.	19.2	35.4	30.0	43.4

It might be interesting to compare the results in Table IV. with those in Table V., where a steel almost identical in composition is used, but with this difference, that oil hardening is adopted in order to produce the high elastic limit called for in steel that has to be used in the manufacture of large guns.

TABLE V.—*Forgings for "Vickers" Guns (Heavy).*

	Analyses.					Treatment.	Position.	Tests.		
	C.	Mn.	P.	S.	Si.			Yield Point.	Ultimate Stress.	Elongation on 2".
6-inch Guns								Tons.	Tons.	Per Cent.
	29	47	029	031	118	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	24.5	40.8	19.0
							B.	23.4	39.9	20.0
	29	49	031	031	120	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	22.5	39.0	20.0
							B.	24.3	40.3	20.0
	30	48	027	027	103	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	21.9	37.6	19.8
							B.	22.4	38.1	22.0
	29	47	026	019	108	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	23.3	40.3	20.0
							B.	21.5	37.0	23.0
	27	47	029	032	112	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	24.2	40.8	19.0
							B.	22.4	38.0	23.0
12-inch Guns	31	47	027	022	116	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	23.3	39.9	22.0
							B.	24.2	40.3	22.0
	31	83	032	031	133	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	25.5	43.0	18.0
							B.	23.3	38.5	20.0
	32	79	031	029	123	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	26.9	45.29	20.0
							B.	24.2	42.15	21.5
	32	81	028	031	138	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	26.45	47.53	23.0
							B.	25.11	46.18	18.0
	28	76	031	033	128	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	26.45	44.3	22.0
							B.	23.31	38.11	23.0
	29	74	027	025	093	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	26.0	43.49	21.0
							B.	22.4	38.11	26.0
	30	82	029	026	123	{ Oil hardened at 1650° F. Annealed at 900° F. }	M.	26.5	43.4	22.0
							B.	23.1	41.5	23.0



It would be a simple matter to extend these tables to any length, but it would serve no useful purpose. When the composition of the steel is regular, the heat treatment is the same, and the results themselves are very regular.

TABLE VI.—*Hollow Forged Nickel Steel Forgings.*

Analyses.						Position.	Tests.			
C.	Mn.	P.	S.	Si.	Ni.		Yield Point.	Ultimate Stress.	Elongation on 2".	Reduction of Area.
							Tons.	Tons.	Per Cent.	Per Cent.
·35	·65	·029	·030	·112	3·4	... T.	36·0	50·7	16·5	34·6
						B.	40·3	53·3	16·5	36·7
·36	·66	·026	·027	·098	3·4	... T.	43·0	50·36	19·5	44·5
						B.	41·2	54·7	16·5	36·4
·36	·64	·028	·029	·086	3·5	... T.	39·0	52·9	20·0	49·0
						B.	38·5	51·4	17·0	37·9

In Table VII. are given a typical series of crank axle tests. Here again much importance is attached to the chemical purity and regularity of composition of the steel used. All were oil hardened at 1650° F.

TABLE VII.—*"Vickers" Crank Axles.*

Analyses.					Treatment.	Tests.				
C.	Mn.	P.	S.	Si.		Yield Point.	Ultimate Stress.	Elongation on 2".	Reduction of Area.	Position.
·28	·81	·029	·031	·118	...	Tons. 17·6	Tons. 32·5	Per Cent. 30·0	Per Cent. 48·0	Web.
·28	·82	·028	·030	·096	{ Annealed at 1000° F.	15·6	32·0	36·0	51·6	Top.
						15·2	31·4	36·0	52·0	Bottom.
·30	·78	·023	·029	·128	{ Annealed at 1100° F.	16·6	33·6	35·0	54·2	Top.
						16·0	32·8	36·0	53·8	Bottom.
·30	·81	·028	·029	·119	...	19·2	34·8	30·0	40·4	Web.
·30	·78	·030	·028	·126	...	19·8	33·6	31·4	57·5	Web.

In Table VIII. below the form of the forgings were such that rapid cooling in air could be adopted as a thermal treatment.

TABLE VIII.—*Small Forgings, "Vickers" Steel.*

Analyses.					Treatment.	Position.	Tests.		
C.	Mn.	P.	S.	Si.			Yield Point.	Ultimate Stress.	Elongation on 2".
							Tons.	Tons.	Per Cent.
38	86	027	031	138	{ Heated above critical point, cooled rapidly in air }	T.	19.2	37.6	28.0
						B.	18.8	38.2	29.0
40	84	028	033	151	{ Heated above critical point, cooled rapidly in air }	T.	19.4	38.6	30.0
						B.	19.6	38.8	30.0
40	83	028	029	148	{ Heated above critical point, cooled rapidly in air }	T.	19.0	38.6	30.0
						B.	19.0	37.6	30.0
41	79	028	031	159	{ Heated above critical point, cooled rapidly in air }	T.	21.8	37.4	28.0
						B.	21.2	37.6	30.0

*Oil Hardening.*—That form of thermal treatment known as "oil hardening" is very interesting, owing to its having been adopted by ordnance manufacturers for a number of years. The author has no intention of dealing with the historical side of the question. Long experience has proved that the process gives the structure and special properties required for ordnance steel, and would also seem to indicate that it still remains the best method of obtaining the desired results. For ordnance work a steel having a high elastic limit is required. This could, of course, be secured by using a higher carbon steel, heating above the critical point and cooling in air, but we have already seen that the difficulty in making large forgings increases with the carbon. Gun tubes are heavy and difficult forgings, but their tubular form, with comparatively thin walls, lends itself to a thermal treatment in which the rate of cooling is considerably accelerated, and the required tests can be obtained easily with a 0.30 carbon steel. The intelligent use of the results given by

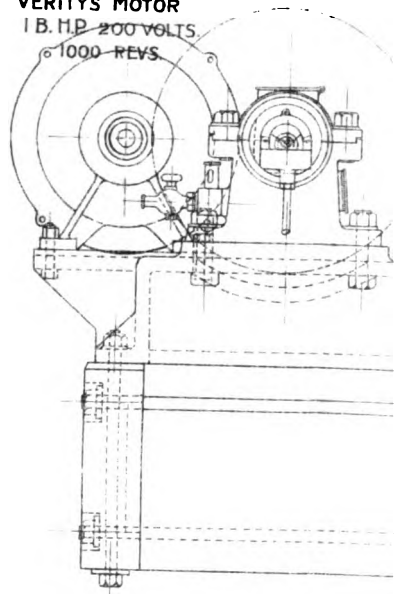
the chemical and physical tests, enabled the process to be successfully used in past years, and now that more light has been thrown on the structural changes that take place in the steel itself, the methods adopted remain the same. The process is simple enough, though it requires a large plant when long forgings have to be treated. They are raised to a temperature well above the critical range, quickly immersed in oil and allowed to cool. They afterwards are heated to  $1100^{\circ}$  F. and allowed to cool slowly. In practice it is better to re-heat the forgings up to  $1100^{\circ}$  F. than to stop the rapid cooling at the same point and then to cool slowly. If the forging warps or twists, it is rectified and is then ready for the final machining. The effect of the treatment is to cause a sudden segregation of the carbide of iron, not into the sharply-marked crystals of pearlite as in annealed steel, but into more indefinite areas of sorbitic pearlite. These areas are more diffused than would be the case with the pearlite of annealed steel, and would retain some of the hardening carbon, hence the raising of the elastic limit of the steel. It would also appear that the cohesion between the ferrite and sorbitic pearlite is greater than with ferrite and pearlite, probably owing to the line of demarcation being less strongly marked. In any case the steel so treated has a comparatively small grain, gives a high elastic limit with a good percentage of elongation. That these results can be obtained from a steel sufficiently low in carbon to be worked in large masses constitutes the great value of the process to the ordnance manufacturer (Plate XI.).

*Vibratory Tests.*—The author has referred to the endurance tests which are made at the River Don Works. On Plate X. is given particulars of the type of machine used. It has given satisfaction in use, and takes up little space. It may have been noticed that endurance tests have not been included in the tabular results given above. The reason is that in no instance have they shown any want of agreement with the static tests, while the mere recital of the number of revolutions a particular test-piece ran before it broke, would convey no information unless they could be compared with the results obtained on other machines under similar conditions, with the same ratio of load to elastic limit. The endurance is proportional to, and depends upon, the elastic limit.

*Conclusion.*—The author has now briefly reviewed the special products which comes within the scope of this paper. It might be objected that the variations in the results are small, but that very regularity is the object aimed for in the works, and its attainment the proof of the correctness of the methods adopted. It would be easy to have extended the tables dealing with tires, axles, guns, shafts, &c., but there would have been the same close agreement between the chemical composition and the tests, having regard to the treatment the steel had undergone. One thing to be emphasised is, that where the steel is to be used in the forms that have just been described, chemical purity is essential. The danger of segregation in large ingots is ever present, though, as the author has shown, it may be diminished by correctly designing the ingot, and this can best be minimised by starting with pure materials. The next point is that the steel should be "well killed." It should teem quietly, and remain still and limpid in the moulds. The piping should be distinct and blowholes entirely absent. Any attempt to secure this by large additions of deoxidisers to the ladle will only result in great variations in the composition of the steel, while there will be the further difficulty that the oxides thus formed would have no time to rise to the surface, owing to the depth of the steel in the ladle or mould. The effect would be seen in the erratic behaviour of the test piece and its discordant results. This is the reason why the basic process is so utterly unsuitable for steel products such as those described here. If the basic process were used, the steel would have to be recarburised and deoxidised outside the furnace, and, as we have seen, this is not suitable so far as high-class steels are concerned. The basic process has its own proper sphere of operation, but the limits of that sphere are very strongly defined. The author next emphasised the importance of casting the steel in open moulds with properly designed heads, and of refraining from attempting by extraneous pressure to compress the fluid steel when the most that could be achieved would be to diminish the volume of blowholes that should never have existed. Lastly, he hopes that he has succeeded in indicating a few of the special conditions that determine, in works practice, the methods adopted for securing the desired results. It has been seen how in

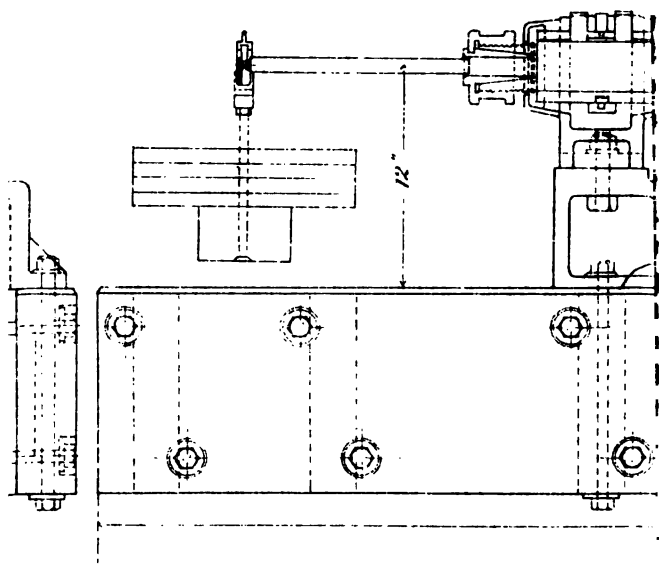
tires a suitable structure has been obtained without any thermal treatment, while the remarkable capacity shown by these tires for resisting wear testifies to the correctness of the principles on which their manufacture is based. In axles, gun tubes, &c., oil hardening is the thermal method adopted; while certain other forgings, possessing as they do a suitable structure when they leave the forge only require annealing from a comparatively low temperature to relieve any strains set up in forging. Other forgings require heating above the critical range, and rapid cooling in air. If the author has succeeded in sufficiently indicating some of the conditions which differentiate works from laboratory practice, the object for which this paper was prepared will have been achieved. He desires to express his obligation to Mr. T. E. Vickers, Chairman of Directors, for permission to use the information given in the paper, and to thank Mr. A. P. Hill, testing engineer, and Mr. J. H. S. Dickenson—who did the micrographic work—for their kind assistance in its preparation.

VERITY'S MOTOR  
1 B. H.P. 200 VOLTS  
1000 REVS.



## DUPLEX VIBRATORY TEST

VICKERS SONS AND MAXIM L



IG MACHINE.

SHEFFIELD.

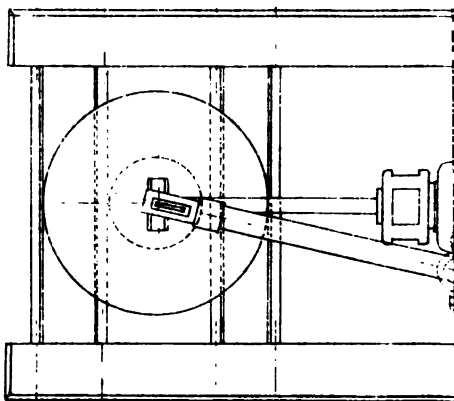
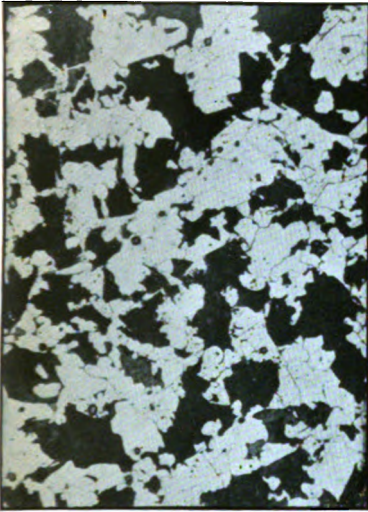
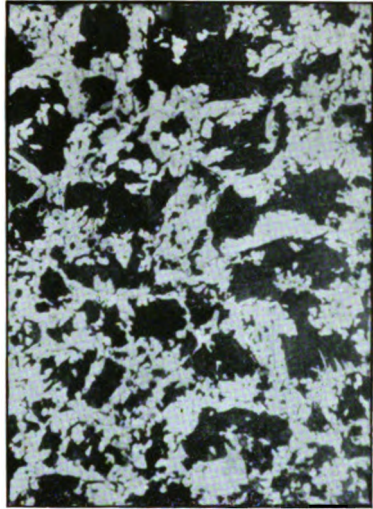


PLATE XI.



*Top End.* 90 diams.

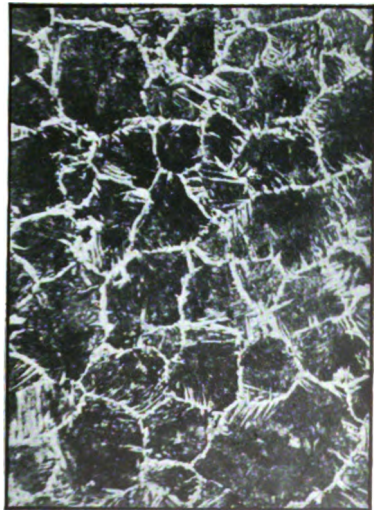


*Bottom End.* 90 diams.

**ANNEALED STEEL SHAFT.**



*As Cast.* 90 diams.



*Forged and Oil-hardened.* 90 diams.

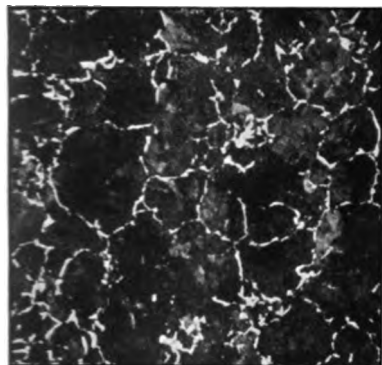
**GUN STEEL.**





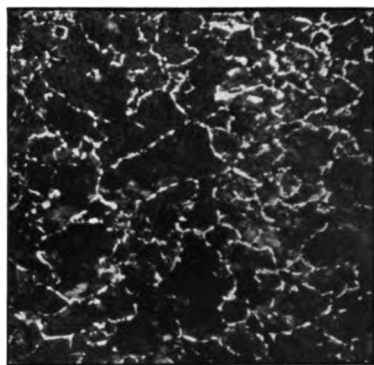
THE STRUCTURE OF A TIRE.

PLATE XII.



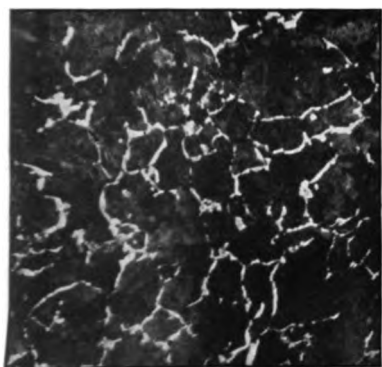
A

90 diams.



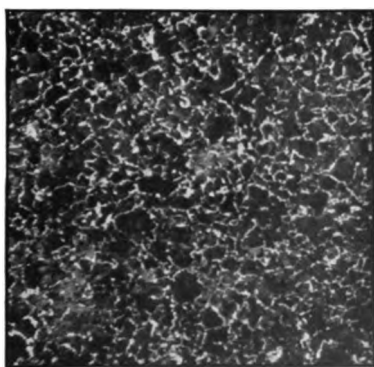
B

90 diams.



C

90 diams.



D

90 diams.



*DISCUSSION.*

Mr. W. F. BEARDSHAW (Sheffield) said the treatment of steel in masses was only second in importance to the composition of the steel itself, and if they had various iron alloys put together in the name of steel, the question was how they could use those steels to the best advantage. Mr. Johns had pointed out how different the experiments were in a laboratory to when one was dealing with large masses of steel. That also applied to the variety of the masses of steel where one found a great difference in the treatment in different masses. For instance, two or three years ago his own firm had been busy with the manufacture of saws for cutting metal. They found that where the steel was  $\frac{1}{4}$  inch thick they got successful results, but if it were  $\frac{3}{8}$  inch thick, with similar heating and quenching, they could not get identically the same results. That led him to make a series of exhaustive experiments, with a view, if possible, to standardising the thermal treatment of steel. Some of the members had no doubt made similar experiments within a limited area. From  $\frac{1}{8}$ th of an inch thick to  $\frac{7}{8}$ ths of an inch thick, the variation of an eighth made a difference in the heating and quenching and gave different results. He had a few results which might be compared with Table V. of Mr. Johns' paper. With steel about 0.30 they could get very much higher results with oil hardening and annealing than the author had given in Table V. For the information of the members he would give two different sizes with the results. In bars  $1\frac{1}{2}$  inch square they got an ultimate tensile 49.38 tons, a yield point of 38 tons, and an extension of 23 per cent.; in  $6\frac{3}{4}$  inches round they got an ultimate tensile of 57.86, a yield point of 45 tons, and an extension as high as 18 per cent. They found, however, that it was not only differences in dimensions, but they got a difference from the outside of the bar compared with the core. There was a vast field for research, and he hoped that the matter would be fully discussed, and that the technical schools at Sheffield would give careful attention to the matter. It would take more time than a single manufacturer could afford to take a further step than that which Mr. Johns had already taken. In connection with practical experiments the working

of the steel made a considerable difference whether it was from a 14-inch or a 10-inch ingot; to bring it down to the same diameter,  $6\frac{3}{4}$  inches, there would be a difference in the ultimate tensiles and the yield point. He was glad to hear that there was going to be an exhibition of pyrometers that afternoon, because the question of the pyrometer was one of the first importance in connection with thermal treatment. He would recommend the use of two separate pyrometers to be used in the same furnace, so that one might check the other. In lowering the heat of the furnace one did not lose the heat so much in the walls of the furnace as in the interior, and they had to be careful that the pyrometer did not register the heat of the walls of the furnace rather than the interior. With regard to the difficulties of warping, that was for the practical steel worker to deal with. All steel, particularly when over 6 feet in length, warped more or less, in the quenching particularly. He considered one point in Mr. Johns' paper was of very great importance, and that was where he said that "the endurance is proportional to and depends upon the elastic limit." He would be heartily glad if the Council of the Institute could give a Carnegie grant for making tests of steel in relation to endurance as compared with elastic limit. It would be indeed of great value to the practical steel-maker. If that were done they might find afterwards that the elastic limit could be detected otherwise than by the usual test. At the Manchester trials of high-speed steel it was found that steel of a definite elastic limit took a definite power to machine, and if some enterprising engineers—Messrs. Vickers themselves, perhaps—would make a series of tests to find if they could get at the elastic limit of a shaft or a bar of steel at the time they were machining it, it would save many difficulties with regard to forgings where test-pieces had to be taken off. He merely threw that out as a suggestion, but he thought it was a matter which, in connection with the thermal treatment of steel, might be of value for a research paper.

Mr. J. M. GLEDHILL, Member of Council, thought he ought specially to say something on the paper, because he was connected with a rival firm to that of the author, the firm called Armstrong, Whitworth & Co. He dared say that Mr. Johns had

heard of it at some time or other. They were competitors, friendly rivals, but he could not let one subject pass in the paper without comment. Possibly the author had an inkling of it already, for it was the question of the fluid compression of steel. Before touching on that subject he would, however, like to congratulate the author and his firm on their largeness of mind in coming forward and giving such information contained in the paper on the treatment of large masses of steel, which was very valuable, because it was so difficult to get, and was only obtainable from people who dealt in heavy masses and had expensive plant. He thought they were indebted to the author and his firm for giving them the results of their experience. He could confirm most of it. It was their own practice, and the figures which Mr. Johns had given were very much the same as his own firm's figures, generally speaking. He was rather surprised to see that no heat treatment was given to tires after they were rolled. He would have thought that it would be a very important thing to have annealed such a critical structure as a tire; if anything happened to it it might prove most disastrous. He would have thought that oil tempering would have tended to improve a tire and then subsequent annealing. The heating of the tire referred to later in the paper, he understood, was of a low temperature, and would not affect the improved structure of the steel due to oil hardening and annealing. It seemed to him very late in the day indeed for any one to come forward and question the advantage of fluid pressure on large masses of steel—he would be very careful in what he said—in circular ingots; ingots circular in section, and used to produce circular forgings such as shafts and gun jackets, or anything of a circular nature. A good deal of nonsense had been attributed by many people to the advantage of fluid compression. Some people had said that it improved the steel chemically. Of course that was ridiculous. Messrs. Armstrong, Whitworth & Co. had never said anything of the kind. Fluid compression was purely a mechanical action—it was where the mechanic came on after the chemist left off. The late Sir Joseph Whitworth, who was the first to compress steel in the fluid state, was essentially a mechanic and not a metallurgist, and he brought his mechanical ability to bear on improving the homogeneity of steel ingots

by the application of fluid compression. He might be pardoned for saying that his (Mr. Gledhill's) father was associated with Sir Joseph Whitworth for many years on that particular process, and undoubtedly a great success was made of fluid compression in producing in large ingots what Mr. Johns had said was difficult to get by heat treatment, namely, homogeneity and regularity, and the absence, in the cast ingot, of initial blemishes, seams, fissures, lines, and cracks. One got regularity by fluid compression. Some two or three months ago he was discussing the matter with a gentleman who was at the head of a large steel works, a man of very great ability who understood how to melt steel well. He would not tell them his name, but he dared say Mr. Johns knew it very well indeed. They were discussing the question of fluid pressure in a quiet way, but it became a little heated before it was over. He told his friend that if he would come to their works he would show them the proper way to make a large steel ingot by pressing it in a fluid state. His friend said he would see him hanged first. However, there was a sequel to that. The following morning he was standing in a group of people together with his friend, and one of the latter's staff was also in the group. His friend said to the member of his staff, "George, is that a very serious crack in that long shaft?" and the reply was, "Yes, it runs about 2 inches, and it is a good many feet long." He (Mr. Gledhill) thought this a curious sequel to their discussion. If his friend had subjected the ingot from which the shaft was made to fluid compression there would have been no crack there. Another point in regard to the fluid compression of ingots was economy. The mechanical action of fluid compression was very economical, and gave a homogeneous ingot. With regard to the question of economy. What little segregation or piping there was was at the top of a pressed ingot and in the centre, was located in such a position that they always knew exactly where to find it. They did not say it was absolutely sound. That was another misstatement which was made. When the Russian Government some years ago wisely adopted the Whitworth system, they thought that if they only put enough pressure on they could squeeze out the little bit of piping, and they kept on trying, putting more and more pressure on it till they finally

reduced their ingot mould to the shape of a barrel, and they could not get the ingot out. After spending a lot of money they left the ingot inside.

Proceeding to the question of economy, fluid compressed ingots were particularly economical in the manufacture of hollow forgings. Most of the forgings were hollow—shafts, gun tubes, and so forth. They trepanned out a piece at the top, bored the remainder for the reception of a mandril, and forged the ingot down on that mandril, and the entire loss did not exceed 5 per cent. That was one of the chief advantages of fluid compression—economy. If, on the other hand, one came to the ingot with what was called a deadhead, that was all scrapped, and one had a considerable loss. That was the difference between the two as regards economy. They put on that head just the same as people who did not use the fluid compression—people who were behind the times like their competitors were. They did not put it on in the nature of a deadhead or waste metal, but they put it on mechanically and thereby had no deadhead. It was the other people who had deadheads. Then again, to go a little further, he thought it was rather late in the day to attack the system when they considered who had adopted it. The Gun Foundry Board of America sent round a commission some years ago to inquire into the best system of producing large masses of steel, steel ingots, especially for the guns, and they decided that the Whitworth system of fluid compression was the best, and it was adopted by the Bethlehem Steel Company, who now pressed all their ingots with a pressure of about 10,000 to 12,000 tons. He had yet to learn that a gun foundry Board, such as that which America sent round, would put down an expensive plant such as that if they did not see there was some advantage in it. Then again there were the great Creusot works in France. The late Mr. Henri Schneider himself came over to this country and spent some two or three weeks inquiring into fluid pressure. The result was they followed the Americans, and had adopted it, and had a large plant made by his firm, for compressing fluid steel ingots. He had already said that Russia had had it for many years. He was told that even Sheffield were already pressing ingots—one of the well-known firms there. It was not the Whitworth system, he believed, but it was fluid



compression. He also heard incidentally that a firm at Glasgow was doing it. They knew that other French firms were doing it, so that it seemed rather late to say that it was useless, unless all these people were wrong. On the question of homogeneity he would point out that with an ingot which had not a lot of pressure upon it there was a tendency to separate in cooling—to pull slightly on the skin of the ingot—and those little pulls, although comparatively insignificant in the ingot itself, when that ingot came to be drawn out and enlarged—an ingot say 18 or 20 feet made in an enormous length of shafting of 60, 70, or 80 feet—those little separations became a serious matter; in fact they were the cracks which friend George had referred to, the 2-inch cracks. If his friend had only had pressure on they would never have had those. So much for the homogeneity question—one got rid of those little cracks. The author stated in his paper that it was better to have an ingot in the round form, and that it would be an advantage if the entire mould were lined.

Mr. JOHNS said that he had not stated that in any part of his paper.

Mr. GLEDHILL said that he rather gathered that was the case.

Mr. JOHNS said he stated that circular moulds were rarely used, and then only when the ingots were comparatively short.

Mr. GLEDHILL said the author stated: "If the entire mould were lined with a non-conducting material many of the difficulties encountered in making large ingots in chilled moulds would be removed." A certain amount of separation took place at those points, and when one came to forge those down and diverted the shape of the ingot into a round ingot, one had a series of lines liable to crop up on that round ingot, which were lines of weakness. They had been found to be the case. It was undesirable to change the shape of an ingot into what it was going to produce eventually, as internal strains were set up, and cracks developed. If one wanted to produce a round, it was best to have a round ingot, but, as the author had stated, there

were difficulties in producing a round ingot in a chill mould. One was liable to get cracks. Whatever he might have said on that matter he hoped that the author would take it in good part, purely from the scientific point of view. He was very glad to have had an opportunity of saying a word or two on the subject.

Mr. F. W. HARBORD (Cooper's Hill) said he had read the paper with considerable interest, because one of the great difficulties they had to deal with in experimental work was the difficulty of dealing with large masses. With regard to all the experiments on small bars, it was their poverty and not their will which consented to the use of small bars, and they would be only too glad to deal with 26-inch rounds if they had the necessary funds.

The most systematic series of experiments made on heat treatment of fairly large bars, so far as he was aware, was the series carried out by Mr. Campion, Carnegie Scholar, and published in his paper last year before the Institute. He found that the centre of the bars varied considerably from the outside, confirming the results referred to by a previous speaker.

There was one point he wished to call attention to on page 64 of the paper; namely, a sentence which he thought required a certain amount of qualification: "Steel made by the basic process would be quite unsuitable for the manufacture of the products referred to in this paper." If the author meant by that a steel made from phosphoric pig iron he was entirely in agreement; but if the author meant a steel made from the same quality of pig iron as used in the acid process—namely, high-class hæmatite—he disagreed. Some of the finest steel was now being made from non-phosphoric pig iron in a basic furnace, and on both in America and the Continent this was being done on a considerable scale.

The quality of the final product depended mainly upon three things: (1) To be able to finish with a practically neutral slag to avoid over-oxidising the metal; (2) the complete removal of impurities to obtain a steel low in phosphorus; and (3) recarburisation in the furnace itself. All these conditions were fulfilled in a basic Siemens furnace working with hæmatite pig iron, a steel of exceptional impurity being produced, and there

being no difficulty about recarburising in the furnace, as the slag is for practical purposes non-phosphoric. Only recently he had followed carefully in detail a number of charges of steel made in a small basic furnace, and there had not been the slightest difficulty in making steel from 0.10 per cent. to 1.30 per cent. of carbon; it was of exceptionally good quality, both as regards mechanical properties and chemical composition, the phosphorus in no case exceeding 0.02 per cent., and generally being under 0.01 per cent. Most of these results he had verified himself, and there could be no doubt about the quality, provided one started with a pure material.

In America and Germany a very large quantity of axle and tire steel was made on these lines, and there was no reason to suppose that such material was inferior to that produced by the acid process in England.

There was one other point he would like to ask the author for further information on, and that was with regard to the vibratory tests entirely confirming the tensile tests. This was not his experience. The vibratory tests were at present not very satisfactory, and probably the results were influenced by various factors which required much further investigation, and from numerous experiments at Cooper's Hill he had come to the conclusion that it was extremely difficult to get absolute results. It must always be borne in mind, as had been pointed out by a previous speaker, that these vibration tests to be of real value must be made so that the stress did not exceed the elastic limit, and he should like to know if all the author's results were obtained under these conditions.

Mr. A. McWILLIAM (Sheffield) said he wished to congratulate Mr. Johns on the general tone of his paper. The author had uttered a word of warning to those who were compelled to work with comparatively small masses, but he had not said what was sometimes said in that connection, namely, that these results were worthless. The author admitted, what was admitted by many connected with practical work dealing with large masses, namely, that these results were very valuable, but that, to be applied to works-practice where the masses dealt with were so much larger, they must be modified by experience in con-

nection with those masses. It reminded him of a very important manufacturer who had said to him at one time: "We keep watching you fellows to see the type of results you are getting, and then we know in a general way how to modify them." Mr. Beardshaw, who had spoken first in connection with the paper, was not the man who said that, but he thought he was one of those who watched such results very closely. He congratulated the author on the correctness of his terms. It was more troublesome to use correct terms, but it made the paper read so much more sweetly. Despite the very able advocacy of the fluid compression of steel which was given by Mr. Gledhill, who was interested in the subject, he thought that most of those who watched from the outside would agree with Mr. Johns. He thought with regard to most of the arguments so ably given, if they were considered in connection with the difference between modern practice and the practice existing at the time when fluid compression made its name, there would be a very considerable difference in the opinions held in connection with it. He had had the great privilege of seeing the method which was used by Messrs. Vickers for reducing pipe to a minimum when making ingots from sound steel, and one must be very much delighted with it. He was the more delighted with it because in connection with crucible steel manufacture, on which at one time he was practically engaged, he managed to use a refractory material in a similar manner for 6 or 7 inch ingots, and by making the refractory top very hot, he could bring the loss down to about 2 lbs. per ingot. He had not before seen it used on such a large scale as on the ingots he saw at Messrs. Vickers'. Having regard to the piping and the small amount of collection of any of those materials which were brought in, and the further remarks which were so well stated in the paper with regard to the proper treatment of material in its manufacture and proper treatment in the furnace, he thought that such steel would still compare with any fluid compressed steel in the world. With regard to the melting, relying upon deoxidising in the ladle was a dangerous practice. That had to be done where people wanted the last shilling in price. Messrs. Vickers, who were making a very high-class material, found they had to do all the deoxidation in the furnace, and not in the ladle. That was a very

interesting point, and he had given it as his opinion to many people who had inquired about the matter. In connection with that point also, it was interesting for the members to compare the ideal ingot of Messrs. Vickers, in which they required freedom from blowholes, with the ideal ingot of Mr. Brinell, which was given to the Institute about two or three years ago. One of the great features in connection with the making of the ingot of Brinell's type was that there must be a few blow-holes. But if one used the dodge adopted by Messrs. Vickers one might have an ingot without blowholes, the ideal desired by all makers of steel, if the piping trouble were mastered. He knew it worked very well by breaking up 6 or 7 inch ingots treated in this way, and, he supposed, by elaborating the details it must work well in other cases also. At the present he was engaged in connection with certain vibratory tests. The paper had been extremely carefully written, so that he hardly thought it was a careless remark, but he would like to hear whether the author still stuck to the point that vibratory tests followed the tensile tests, and if it was really the case that they were proportional to the elastic limits. It might be the case if those tests were kept below the elastic limits. As was well known to members of the Institute, tests were being made at the University College, Sheffield, and in each case the material was taken slightly beyond its elastic limit so as to get the test finished more quickly. Perhaps that might account for the difference. But although they got an idea of the inner quality of the steel itself in a way which they hoped to put before the Institute before very long, the vibratory tests were not exactly in line with the tensile tests. These were the only points he wished to mention, but he begged to congratulate the author on his paper, its great intrinsic value, its general tone, and on the quality of the photomicrographs.

Mr. F. J. R. CARULLA (Derby) said he really could not let the discussion pass without congratulating the author upon his extremely valuable contribution, if only for the discussion which it had elicited. Mr. Gledhill had explained thoroughly the use of fluid compression. Before hearing that speech he was afraid that he would have agreed entirely with what Mr. Johns had

said in the paper. It was very difficult to see how any liquid was going to be modified by compression. One knew that a fall of temperature as a general rule reduced the volume, but compression could not do so. Consequently it was not obvious how compression was going to improve a liquid ingot. Of course they knew very well that stoppering was a very useful process, but stoppering, which was a sort of fluid compression, was really a precaution to prevent one from obtaining steel sponge instead of ingots from a rising heat. With regard to the question of basic steel not being applicable for those very pure products, he thought that practice would overtake theory. Theory unquestionably showed that the finest steel could be produced from the basic furnace, and it seemed to him that eventually this will be done.

Mr. COSMO JOHNS, in reply, said that there were several points raised upon which information had been requested, and as other communications dealing with the paper might be sent, he would prefer to reply to these in writing. In reply to Mr. Beardshaw, he would point out that the higher tests that gentleman had obtained were with small specimens, in fact, simply laboratory experiments. One could not compare such results with work done on a shaft like that of Table III., or heavy gun tubes 50 feet in length, where rigid specifications limited the results, and the test-pieces had to be taken from specified positions. It was a comparatively easy matter to get these high tests with small pieces of steel. What he (Mr. Johns) had been endeavouring to explain was the difficulty in producing results with large masses. Mr. F. W. Harbord understood that the quality of steel depended upon its percentage of phosphorus and sulphur. But was there not an element possibly of equal importance, viz., oxygen? It was in his opinion—if any member could disprove, he would, of course, listen to the arguments—impossible to make tires, axles, or ordnance steel of the quality mentioned in the paper in a basic furnace. A basic furnace meant a basic slag. With reference to Mr. Gledhill's remarks, he noticed that that gentleman was anxious to give him credit for advocating the use of circular moulds. He (Mr. Johns) maintained that circular moulds were wrong in principle, and in

that he was supported by every one who had experience in that class of work. The circle gave the smallest perimeter for a given area of any figure selected, and thus gave the least cooling surface. Cooling would thus be at a slower rate than with any other form. Either square or octagonal would be better than circular. At the River Don Works, circular moulds had only been used for very small ingots, and even these were now being replaced by other forms. As described by Mr. McWilliam, the form of mould used for all work was a chill body to contain the portion of the ingot destined for use with a head lined with non-conducting refractory material, so proportioned that it should remain liquid until the body had solidified. This feeding or sinking head being the last portion to remain liquid will contain the segregation region where the segregated impurities occur. There were difficulties, of course, attending the use of this ideal method of casting ingots, especially for large sizes. People who could not overcome these difficulties naturally adopted a circular mould lined over its length with non-conducting material, though, as was shown in the paper, this method was attended by serious results, owing to piping and the segregation region occurring in the portion of the ingot used. He (Mr. Johns) had given in the paper an instance of a large ingot where there was only a difference between the two ends of 0.01 per cent. in carbon, 0.03 in manganese, very little in the silicon, while the phosphorus and sulphur were the same. That was almost an ideal ingot. That result was not obtained by attempting to work with 5 per cent. loss. It would be noticed that Mr. Gledhill had not met or even discussed a single one of the arguments based on scientific reasoning directed in the paper against fluid compression. His sole argument was that its adoption would save a little in the weight of the ingot. But in products of such great importance as shafting for ships, high-class railway material, guns, &c., it was important that nothing should stand in the way of quality. At Sheffield no account was taken of how much it was necessary to discard. That portion only of the ingot was used which was as nearly perfect as they could have it for the purpose required. If he could not hear of any better arguments for establishing the possible benefits of fluid compression he would have to conclude—and he thought the members present

would also conclude—that his statements were correct. Any further remarks would be communicated to the Secretary later on.

The PRESIDENT then asked the members to accord a very hearty vote of thanks to Mr. Johns for the remarkable paper which he had read. He said: I would also like you to thank Mr. Gledhill and the other speakers. I certainly have the impression now that I really know something about the casting of steel—the circular form and the angular, head-piece, and fluid compression. I think Mr. Johns rather dwelt on the point, that an ounce of prevention was worth a pound of cure. I am sure that we all appreciate Mr. Johns's services to the Institute; that a member of his great firm should come here and deliver such a paper as that before us merits special recognition. We are also greatly indebted to his great but friendly competitor, who has replied to some of the points in the paper. It has been an object lesson to all, I think, and I am sure that you will never forget it. I move a vote of thanks to the author for his valuable paper.

The resolution was carried with acclamation.

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### CORRESPONDENCE.

Mr. R. M. DAELN (Düsseldorf) writes: The large cavity in the centre of a steel ingot (piping) is due to the fact that the outside skin solidifies first, and the interior fluid mass in contracting draws down the upper surface and a cavity occurs as the outside is already solidified. To obviate this three different methods may be adopted: either fresh metal may be poured in as the ingot cools, or the top kept liquid by external heat, or the ingot subjected to compression as long as fluid metal is present in the mould. The second method is the simplest and cheapest according to the statements of J. Riemer, chief engineer of Haniel & Lueg, Düsseldorf, which appeared in the *Iron and Coal Trades Review*. According to this process the upper part of the



mould is lined with refractory material which is heated by a (producer-gas) burner, and placed on the top of the mould, hot producer-gas and air (a blow-pipe flame) being directed into it and on to the top of the ingot, so high a temperature being produced that the steel is kept melted for from  $1\frac{1}{2}$  to 2 hours. This fills up the central cavity, and reduces the loss by "dead-head" from 25 per cent. or 35 per cent. to 5 per cent. or 7 per cent., as shown in the accompanying illustration. The effect of liquation is also rendered harmless as the parts of the metal rich in phosphorus and sulphur, and those containing the highest percentage of carbon rise to the top and collect the "dead-head," the amount lost in which cannot by any compression process be less than 5 per cent. The Riemer process has been in use in the Haniel & Lueg works at Düsseldorf with the best results for some two years back, and also in various other works.

Mr. H. LE NEVE FOSTER (Birmingham) writes that he cannot agree with the author's conclusions, namely, that basic steel, that is steel made on a basic hearth, is unsuitable for axles, tires, and high-class material. Mr. Harbord has ably pointed out that steel made from hæmatite and low phosphorus pig iron can be made into finest grades of steel on a basic hearth, and Mr. Foster's experience fully confirms this. There is no difficulty whatever in making steel on a basic hearth quite free from defects which rightly or wrongly Mr. Johns attributes to oxygen. In his (Mr. Foster's) opinion it is simply a matter of competent supervision and competent workmen. A bad workman can spoil the best material by any process, but it is not fair to blame the process for such bad work. The bulk of axles and tires used in Germany and America, and the finest quality of girder section iron also, are manufactured by the basic process. He did not think any one would be prepared to condemn wholesale all such basic steel, for surely the practical results of these articles are good enough.

Formerly there was no doubt a great deal of justified prejudice against basic steel, but this generally applies to any new process, and he believes any one who is conversant with what is now being done in basic practice will be able to state that practice has now overtaken theory, and that some of the finest steels

are being produced by the basic process from both low and high phosphorus pig.

Mr. JOHN PARRY (Ebbw Vale) writes: Concerning round *v.* square, or octagonal ingot moulds, he had some experience at Ebbw Vale. Round ingots were preferred by him, the finished product being freer from cracks. Square and other forms were found to be more liable to cracks at edges, the square ones being the worst in this respect. With regard to compressed steel he says he has had no practical experience, but knows that compressed steel contains less gas than the ordinary steel. He thinks, however, that by allowing the fluid steel to rise in a hot mixer, thus getting what is technically known as dead melted metal, practically all the gas can be got rid of.

Mr. ARTHUR W. RICHARDS (Middlesbrough) wrote that he had read Mr. Johns' paper with much interest, and regarded it as a valuable addition to similar papers on the thermal treatment of steel. Mr. Johns, however, had carefully impressed upon them that most of the previous work had been done on laboratory samples. He (Mr. Richards) would therefore remind him that the researches of Messrs. Campion, Stead, and his own, although not on such huge masses as gun-forgings, were exclusively made upon commercial pieces of steel, not in the laboratory but in the works, in such a way as to demonstrate how such treatment can be applied in daily practice. They did not experiment on pieces 60 tons in weight, but obtained the same result on a 5-inch square billet as had been obtained on a small laboratory sample. In the heating of large ingots for forging, such as Mr. Johns describes, they found that whatever care and precautions may be taken, internal crystallisation often occurs, and although such forgings will, when finished, fully answer all tests in the specification, they can be improved by heating to a proper temperature to split up such crystallisation, followed by comparatively rapid cooling, irrespective of the mass, provided one has the facilities for proper heating.

The remarks made by the author on the impossibility of obtaining high-class steel by the basic process are somewhat surprising, as it is the experience of those who have had to work and study

the making of steel on the basic hearth, that it is by it and not by the acid process that the most pure steels can be produced. There is no difficulty now in obtaining steel with the phosphorus and sulphur very low indeed, even down to 0.01 per cent. each, and we would consider the 0.035 per cent. given by Mr. Johns by the acid process as very easy to obtain. Further, the high-class steel of great purity now obtained on the basic hearth needs none of the large additions of deoxidisers in the ladle, as mentioned by Mr. Johns, as it is very solid and quiet in the ingot moulds and gives very uniform results in testing. In fact, it is slowly but surely being recognised in the most conservative parts of England, America, and Germany that steel made on the basic hearth is coming to the front and will supersede the old acid steel.

Mr. RALPH G. SCOTT (Leeds) wrote to say he wished to add a word, with regard to fluid compression of steel, to Mr. Gledhill's very lucid contribution to the discussion of Mr. Johns' paper, which he considered very valuable where he dealt with the processes in vogue at the works where he was employed, but quite unreliable where he referred to practice with which he was unfamiliar.

It was always considered a formidable task to prove a negative proposition, and yet Mr. Johns boldly stated that "fluid compression cannot possibly be beneficial to properly melted steel," in spite of the fact that firms of the highest standing had used the process for years, not presumably for amusement, and at the present time several others were putting down powerful presses for compressing fluid steel. Had the author, Mr. Scott would like to know, made exhaustive comparative experiments with compressed and non-compressed steel and found that there was no advantage in compression?

Again, a few lines before, Mr. Johns said: "The pipe is in a harmless position, while the volume of the head cannot be reduced without danger of the body of the ingot containing the segregated impurities."

This was a rather vague statement and not quite easy to follow, for the body of the ingot must contain the "segregation impurities" in every case—they were not generated in the head!—but

when evenly distributed through the mass they were quite innocuous. This was exactly what was claimed for fluid and plastic compression properly applied, viz., that the head can be practically done away with and the segregation of impurities and carbon prevented, an ingot being produced which is homogeneous from end to end and free from internal pipe and external cracks.

At the Düsseldorf meeting a very carefully prepared paper entitled "Compression by Wire Drawing"\* was read by M. Harmet, and Plate VI. accompanying that paper showed graphically the continued good effect of compression, not, as opponents of the system seemed to think, by reducing the bulk while the steel was in a fluid condition, but by gradually following up the natural contraction of the mass, which took place as the fluid passed through a plastic to a solid condition, and *pari passu* squeezing the ingot up into a gradually diminishing conical space, so that the solidified walls of the ingot were always supported by the inside of the mould, and the fluid inside was continually kept up to the top of the ingot. It might aptly be described as a self-feeding arrangement of casting.

In this process each particular ingot had its own rate of compression, which varied with its cross section, its length, and the class of steel to be dealt with, and the compression had to be carried out to its full extent in order to get corresponding benefit.

One point had been observed by stopping the compression at different periods before completion, and was illustrated in Plate VI. referred to above, and that was, that the last internal defect to disappear was not the pipe in the upper part of the ingot, but a looseness of texture or porosity near the bottom, which could in no way be reached by a head of fluid steel above. The print unfortunately was not clear (Figs. 39 and 40), but the difference in the ingots themselves was most distinct without any magnification.

Those who had been at St. Etienne had had ocular demonstration of the truth of all that Mr. Harmet had advanced in his paper, and a more direct and practical refutation of Mr. Johns' remarks on liquid compression could not be conceived.

Mr. Johns' reply to Mr. Gledhill that "at Sheffield no account

\* *Journal of the Iron and Steel Institute*, 1902, No. II. p. 146 et seq.

was taken of how much it was necessary to discard," could scarcely be considered a good point under present-day management, as it had been shown by mechanical tests and chemical analysis that an ingot could be obtained free from deleterious segregation and greatly improved in its physical condition throughout, by compression.

They were able in this way to get 25 per cent. to 40 per cent. more effective weight from the same amount of raw material, not only without any deterioration, but on the contrary with decided improvement of quality, which seemed to him an economy not to be treated as of "no account" even at Sheffield.

Mr. J. E. STEAD, Member of Council, writes that a paper such as this from a man of Mr. Cosmo Johns' experience and knowledge must be regarded as a valuable contribution. Mr. Johns and steel manufacturers generally have usually to work to specification, and are not always given a free hand to make their steel in the best possible condition.

It was difficult to see why special precautions are invariably taken in making guns, armour plates, &c., used in connection with warfare and the destruction of life, and the same precautions are not always taken when making machinery, &c., upon which human life and property depend.

If it is, as the author admits, that "resistance to vibration stresses or endurance is proportional to, and depends upon the elastic limit," would he not advise, where steel engine and other forgings have to be subjected to vibration stresses, that they should be treated in such a way as to raise the elastic limit and so increase the endurance?

Would not a propeller shaft, or crank bolt, with an elastic limit of 15 tons, be more enduring if treated in such a way as to raise the elastic limit to 30 tons?

The author did not appear to have faith in basic steel. The objection that all the "additions" had to be made when the steel had left the furnace was not considered serious by those who made basic steel, but accepting the author's view of the matter, it must not be assumed that iron made practically free from sulphur and phosphorus by treatment in a basic hearth can be finished in one way only. He believed that before

many years had passed the basic hearth will be largely used in Sheffield: that to meet the objections such as have been raised by the author, the basic purified iron will be transferred to, and finished in, an acid-lined furnace, and the metal be brought into exactly the same tranquil state as it is when worked throughout in the acid Siemens process.

With the importation of Dunderland briquettes and the introduction of rapid-driving furnaces, the hæmatite pig iron produced will be low enough in silicon and sulphur to admit of its use in the basic hearth. Old rails and every kind of steel scrap will be available, and from such material steel can be produced equal, if not superior, in analysis to the high-class material described by Mr. Johns.

In his (Mr. Stead's) opinion in the near future the best and cheapest steel will be produced on the basic-lined hearth.

Mr. COSMO JOHNS, in reply to the foregoing, writes that criticism may be said to have been directed towards the following statements in the paper:—

- (1) "The tires, though allowed to cool naturally after leaving the rolls, have a well-developed sorbitic structure, and it would be difficult to suggest a treatment that would add in any way to their wearing qualities or increase their resistance to shock."
- (2) The "fluid compression cannot possibly be beneficial to properly melted steel."
- (3) That "steel made by the basic process would be quite unsuitable for the manufacture of the products referred to in this paper."
- (4) "That the endurance is proportional to and depends upon the elastic limit."

While giving these conclusions in the paper, the author was careful to use terms as explicit and clear as possible, so that the discussion that followed might be confined within reasonable limits. He also mentioned that they referred to the special products described in the paper—an important point that was overlooked by several contributors to the discussion.

No very serious objections were made to (1) and (4); but there was evidently a marked difference of opinion as to (2) and

(8), due in most cases to those taking part in the discussion having read into those paragraphs a meaning never intended by the author.

The question whether tires should receive thermal treatment after rolling, other than to be allowed to cool naturally in the air—care being taken of course that no stresses due to irregular cooling are set up—can easily be decided. It will be admitted that the micro-structure, now known as sorbitic, is the most suitable to resist wear and shock.

Now the presence or absence of this particular micro-structure can easily be determined. If, as in the case of Vickers tires, that process is well developed, by what process of reasoning can the adoption of a special thermal treatment be advocated? It is, however, the life of a tire under service conditions that constitutes the final test, and it is by that test that the method used at the River Don Works has been proved to be the correct one.

The discussion on the desirability or otherwise of subjecting steel to "fluid compression" is rather remarkable for the fact that nearly all the contributors confused "fluid compression" with something very different. Even Mr. Gledhill in his defence of the Whitworth system refers to the adoption of other systems in several districts, and says that "it was not the Whitworth system, but it was fluid compression." Now if fluid compression means anything at all, it involves an increase in the static pressure of the steel over and above that due to its depth. Among the various systems referred to in the discussion, there is only one where the ingot is compressed by extraneous pressure in a closed mould, and where the fluid pressure is increased. That system is, of course, the Whitworth, and to it alone does the author's objection apply.

In the Riemer system the upper surface is kept fluid by a blow-pipe flame, and in the Harmet system the fluid steel is prevented from sinking, as it contracts during cooling, by a gradual deformation of the solid shell of the ingot. This deformation reduces the capacity of the freezing shell, and maintains the level of the fluid portion of the ingot at its original level. There is thus this distinguishing feature in both systems, that the upper surface remains fluid until the remainder has solidified, and is always open to atmospheric pressure.

The fluid pressure at any point is that due to the depth alone. That Mr. Gledhill should call these systems "fluid compression" would suggest that his information regarding them was not accurate.

Mr. Scott had even less excuse for bringing forward the Harmet system as a proof of the virtue of fluid compression, for he professes to describe that method. Mr. Daelen, however, in his valuable contribution was careful to recognise the distinction between the different systems. Mr. Scott will now probably see that it was the Whitworth system, with its increase of static pressure, that was objected to. The author had no objection to offer against the Riemer or Harmet systems. Their adoption or rejection must depend on local conditions, and it must not be forgotten that when they have achieved their object the only gain will be in the reduction in the volume of head necessary for a particular ingot body. Mr. Gledhill very properly conceded that fluid compression did not improve the steel chemically, and confined his claim to a saving in the weight of the head. Therefore the claim by the author that "fluid compression cannot possibly be beneficial to properly melted steel" has been established. Mr. Scott complains, and rightly too, of one paragraph being vague. This vagueness was due to the substitution of "segregation" for "segregated." This has been corrected. The context showed clearly which word was intended.

The discussion on the relative advantages of the basic and acid processes of steel making went outside the author's contention, which was an objection to the use of basic steel for high-class work, such as ordnance forgings, tires, &c. To argue that plates, rails, girder-beams, ordinary tires and axles can thus be made was to state a truism. To deduce from this that the special products described by the author may be made from basic steel, implies that a clear distinction is not always made between what is known as high-class and ordinary steel. Mr. Stead would seem to have recognised the difference, for he mentions the possibility, often suggested, of finishing the steel in an acid-lined furnace. But if that were done the steel would be acid and not basic, for it is the final and not the preliminary process that determines its character. All the ordnance manufacturers of



repute in the world decline to use basic steel for high-class work, though many of them use it for products of less importance. The fact that in so many countries firms of the highest repute use the acid for making high-class carbon steels is enough to prove that it is not mere prejudice, but some very good reason, that decides the question. The fact that this reason may not be obvious to people whose experience is limited to plates, girder-beams, &c., does not constitute an effective argument.

The question as to the value to be attached to vibratory tests as an indication of the endurance of steel were to show that the author's decision not to include such tests in the tabulated results given in the paper was a sound one, for it is very evident that the condition governing tests that depend on the application of alternating stresses are not generally recognised.

The author's statement "that the endurance is proportional to, and depends on, the elastic limit," refers only to the quality of steel described in the paper. To that statement will now be added another:—

It is only when the stress applied is well below the elastic limit, as determined by the yield point on the static testing machine, that the vibratory test is any measure of the endurance.

This is so obvious, though often overlooked, that the author does not think it necessary to take up space by discussing the proofs. The importance of keeping the vibratory stress well down (50 per cent. of the elastic limit would not be too low) cannot be too strongly insisted on.

In the discussion Mr. McWilliam was the first to call attention to its importance. Mr. Harbord complains of the difficulty in obtaining absolute results. In the author's opinion comparative results are all that can be hoped for. There is, as Mr. Harbord says, "room for much research work in the field," and if it be carried out on the right lines much valuable information would be obtained. If the author's conclusions are correct, not the least interesting of these results would be those indicating the difference in endurance between high-class and ordinary steels.

A number of interesting questions were asked by Mr. Stead. The author agrees with him that the test for propeller shafts, &c., should be made more rigid and the elastic limit increased, but it

so happens that this is the very thing that the manufacturer is prevented from doing owing to the limitations of the specification he is compelled to work to. To have a shaft threatened with rejection because it gives results on the testing machine superior to those required by the specification is not an unknown experience. A reference to the various tables will show the tests that can be obtained from high-class carbon steels after certain forms of thermal treatment. In marine shafting alone is the manufacturer compelled to keep the tests low, and is thus prevented from taking advantage of the great advances made in the metallurgic art.

But interesting though the discussion has been, it should not be forgotten that the object of the paper was to indicate the special conditions that differentiate works from laboratory practice. The theoretical investigator is too apt to exaggerate the relative importance of his particular line of research. The various methods of testing, whether static or vibratory, chemical or microscopical, are all of value. The facts discovered as a result of experiments on small pieces are of course useful, but it still remains for the metallurgical engineer with his works experience of the limits that "mass" implies and commercial requirements stipulate, to receive these sometimes contradictory results, give to each their real value, and out of the efforts of the theoretical investigator to evolve a system of successful works practice.

## PYROMETERS SUITABLE FOR METALLURGICAL WORK.

At the Barrow meeting of the Iron and Steel Institute the suggestion was made that, in view of the growing importance of pyrometers to the steel industry, arrangements should be made to enable members to see the actual working of different pyrometers, in order to enable them to form their own opinions of the relative merits of the appliances available for metallurgical purposes.

The Council readily adopted this suggestion, and appointed a committee, consisting of Mr. R. A. Hadfield, Vice-President, Mr. J. E. Stead, Member of Council, and Mr. B. H. Brough, Secretary, to make the necessary arrangements for the exhibition.

Invitations were sent to all the leading makers to exhibit pyrometers, and to furnish brief descriptions of them; and it is hoped that information regarding their relative merits will be elicited in the discussion.

Descriptions are appended of the following types:—

- (1) Baird and Tatlock pyrometer.
- (2) Bristol's recording air pyrometer.
- (3) Callendar and Griffith resistance thermometer.
- (4) Le Chatelier pyrometer.
- (5) Mesuré and Nouel optical pyrometer.
- (6) Roberts-Austen recording pyrometer.
- (7) Rosenhain and Callendar pyrometer.
- (8) Seger cones.
- (9) Siemens electrical pyrometer.
- (10) Siemens water pyrometer.
- (11) Uehling pneumatic pyrometer with Steinbart automatic recorder.
- (12) Wanner optical pyrometer.
- (13) Wiborgh's thermophone.
- (14) Zaubitz pyrometer.

In conclusion, a list of patents relating to pyrometry and a bibliography of the subject are given.

The Committee desire to thank Mr. A. Campion, Mr. H. G. Graves, Mr. F. W. Harbord, Mr. J. H. Harrison, and Dr. A. Weiskopf for valuable help.

### THE BAIRD & TATLOCK PYROMETER.\*

Made by Messrs. BAIRD & TATLOCK, Glasgow.

This is a variety of thermo-electric pyrometer in which the electro-motive force developed by the difference in temperature of two similar thermo-electric junctions opposed to one another is measured.

The Le Chatelier couple, consisting of a pure platinum wire, and a platinum with 10 per cent. of rhodium or iridium wire, is used. For use at very high temperatures, the platinum and platinum rhodium couple is preferable, on account of its greater durability. The platinum and platinum-iridium couple gives a larger electro-motive force, and consequently a more open scale.

The measuring instrument is a portable form of high resistance dead beat D'Arsonval galvanometer, the coil of which carries a long pointer over a graduated scale reading in degrees Centigrade or Fahrenheit direct. A special arrangement is adopted which prevents the pivots of the needle being damaged. Fig. 1 shows a portable form of measuring instrument; a stationary form of the instrument is also supplied, in which the galvanometer is mounted on gimbals, and is therefore self-levelling. This form of instrument is very convenient when it is necessary to determine temperatures at different points in a large works.

In both forms of instruments the moving part is a rectangular coil of fine wire delicately suspended between the poles of a powerful permanent magnet. The magnets, which are made from a special quality of steel, after being magnetised are very carefully tested for dead-beatness and permanency of readings before being made up. The thermo-couple wires are threaded through short lengths of double-bored porcelain tubes, which in turn are enclosed in an iron or steel outer tube. The instruments are very carefully calibrated before being sent out. The following is the method adopted: The increments

\* This description has been kindly prepared by Mr. A. Campion, Cooper's Hill.

of current furnished by the couple for equal increments of temperature are determined. The current corresponding to the maximum temperature ( $1600^{\circ}\text{C.}$ ) which the instrument is to measure being known, a current of, say,  $\frac{1}{100}$ th of the maximum



FIG. 1.

is sent through the galvanometer, and the position of the needle is noted. The current is then increased by small amounts up to the maximum, and the position of the needle noted for each amount. In this way a scale corresponding to equal increments of current, and therefore to equal rises of temperature, is obtained. It then only requires the accurate determination

of one point of the scale by a melting point temperature to render it an absolute temperature scale. The calibration of the instruments is not affected by their being carried about.

Two forms of recording instruments are also made, so that records of temperatures for lengthened periods of time may be obtained.

*The Pyrograph.*—In this instrument a band of photographic paper is drawn, at a suitable rate, under a very fine slit in the dial. The slit is at right-angle to the motion of the paper, so that if the light of an 8 candle-power electric lamp is shining on the dial, some will pass through the slit and blacken the whole band as it is drawn past. The needle, however, of a dead-beat galvanometer actuated by the thermo-electric force of a platinum and platinum-rhodium couple moves above the dial, and this casts a shadow through the slit on to the photographic paper, and when this is developed the record is seen as a white line. The same clockwork which draws the paper also switches off the lamp for one minute every hour, and thus marks white hour lines across the record. A datum line, say at  $1000^{\circ}$ , is marked on the record by a hair laid across the slit at the point, and by applying a scale to this line on the record, the temperature at any part can be ascertained.

*The Automatic Recorder.*—In this instrument the needle, fixed to a dead-beat galvanometer coil and actuated by a thermo-junction, plays between two rubbing contacts. The torsion wire supporting the coil is hung from a differential gear connecting two pieces of clockwork, and these are controlled by magnets worked by current sent through either of them when the needle completes a circuit through either of the rubbing contacts. The effect is to twist the torsion wire and bring the needle central between the contacts. A lever and pen are also connected to the differential gear, so that the amount of movement needed to bring the needle midway between the contacts is shown and recorded by the pen, which is arranged to write on a drum.

#### BRISTOL'S RECORDING AIR PYROMETER.

Made by THE BRISTOL COMPANY, Waterbury, U.S.A.

This instrument was designed to meet a demand for a pyrometer to measure temperatures of high ranges, and to give con-

tinuous records of changes of such temperatures on a moving chart. It is also arranged to be self-compensating for barometric and thermometric changes of the atmosphere without introducing delicate mechanism which would tend to render it inaccurate.

The pyrometer consists simply of a porcelain bulb connected by a capillary tube to a recording pressure-gauge. The stem of the porcelain bulb is made of sufficient length to pass through

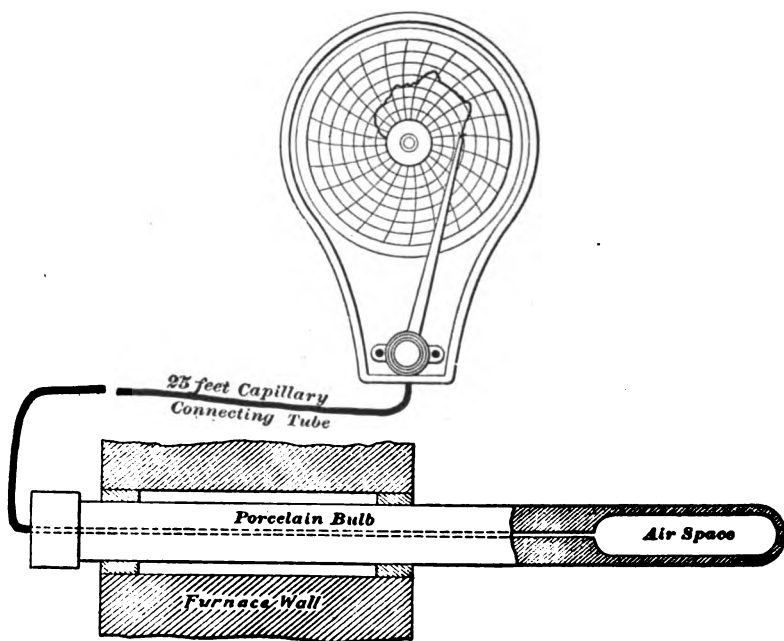


FIG. 2.

the furnace-wall, and the capillary connecting-tube is made of seamless copper. The recording pressure-gauge is constructed on the Bourdon principle, the pressure-tubes being of a closely flattened cross-section, formed into a helix of two complete turns. Two of these tubes are employed, one being the indicating-tube or spring connected to the air-bulb by the capillary-tube, and turned axially by the variations of pressure due to changes of the

temperature to be measured. The other, a compensating-spring, is attached mechanically to the free end of the indicating-tube or spring. This latter is turned axially by variations of atmospheric pressure and temperature in a direction opposite to the motion of the first or indicating-spring. These tubes are made of equal strength; hence external or internal pressure produce the same angular movement in each.

The air-bulb, capillary connecting-tube, and indicating-tube are almost exhausted of air, so that when cold the bulb is subjected to a pressure nearly equal to that of the atmosphere. When exposed to a high temperature the enclosed air is expanded, so as to balance the external pressure, and the bulb is relieved of strains which tend to injure it. The pointer moves upon a flat disc forming the chart, which is revolved by clock-work in the usual manner. The instrument can be calibrated to register temperatures up to  $2000^{\circ}$  Fahrenheit ( $1093^{\circ}$  C.), but the practical working range in its present form is not above  $800^{\circ}$  F. ( $426^{\circ}$  C.). It is the joint invention of E. H. Bristol and W. H. Bristol.

CALLNDAR AND GRIFFITH'S THERMOMETERS,  
THERMO-COUPLES, &c.

Made by THE CAMBRIDGE SCIENTIFIC INSTRUMENT COMPANY, Limited,  
Cambridge.

*Resistance Thermometers.*—In these the increase in resistance of a platinum wire with temperature is observed. The electric-resistance thermometer was first proposed by Sir William Siemens in the Bakerian Lecture in 1871, and it immediately came into general use for metallurgical work. Unfortunately it was found that small changes in the resistance of the thermometer occurred owing to the chemical action on the platinum of the silica in the porcelain bobbin on which the wire was wound. In 1886 Professor H. L. Callendar showed that if the platinum is supported on a mica frame, in section that of a cross with equal arms, there is perfect insulation without any cause of alteration. Professor Callendar also pointed out the importance of protecting the platinum from noxious gases, all volatile metals attacking platinum readily.



The Callendar and Griffith's Resistance Thermometer consists of a fine platinum wire wound on a mica frame, and connected by means of stout copper or platinum leads to terminals in the head of the thermometer (see Fig. 3). Two similar leads, but unconnected with the coil, pass through the whole length of the thermometer and act as compensating leads. By this means no error is introduced by the variation of the temperature of the wires connecting the thermometer with the indicator or recorder. For reading temperature directly by means of a resistance thermometer the Whipple Temperature Indicator is generally employed. It consists of a Wheatstone Bridge



FIG. 3.

one arm of which is a long bridge wire wound in the form of a helix on an ebonite drum. A contact-maker mounted on the inside of a drum can be rotated over this wire. A scale divided into degrees Centigrade or Fahrenheit is fixed on the outer surface of the drum. The four terminals of the resistance thermometer are connected by means of leads to the indicator, the resistance coil of the thermometer thus forming one arm of the bridge. By turning the handle, the contact-maker is moved along the bridge wire until sufficient resistance is introduced to balance the resistance of the thermometer. The galvanometer needle shows when this electrical balance has been obtained. A pointer shows the temperature on the scale previously referred to.

This instrument has been applied with considerable success to the measurement of the temperature of hardening baths, boiler flues, &c.

For recording temperature by means of an electric-resistance thermometer a Callendar Recorder is employed. This instrument, which was designed by Professor H. L. Callendar,

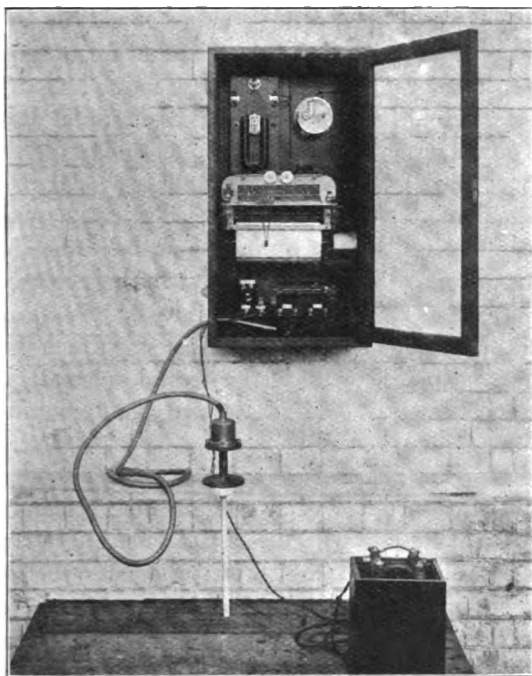


FIG. 4.

consists of a Wheatstone Bridge or Potentiometer, in which the movements of the slider along the bridge wire is automatically effected by relays worked by the current passing through the galvanometer between the bridge-arms. According as the moving coil of this galvanometer is deflected in one direction or the other, a relay circuit is connected through one or the other of two electro-magnets. Each of these magnets is mounted on a clock, the movement of which is prevented by a brake. When a current passes through a magnet this brake

is lifted, allowing the clockwork to revolve. These clocks are connected, by differential gearing, with a recording pen, which is pulled in one direction or the other when the brake is lifted from the corresponding clock. The bridge slider moves with the pen and tends to restore balance.

Fig. 4 is an illustration of a Callendar Recorder with a resistance thermometer attached to it. This thermometer is specially designed for measuring the temperature of annealing furnaces. A record sheet of the temperature of an annealing furnace over twenty-four hours clearly shows the difference in the firing of the old and new hands. Records of the temperature of the downtake of a Lancashire boiler and of the temperature of an air-blast during a week's run are also available.

The Callendar Recorder can be used for the determination of recalescent points, either by means of resistance or thermo-electric pyrometers. It is proposed to draw recalescent curves by means of one of the recorders exhibited. A sample of steel about 3 ins. long and 1 in. in diameter in which a resistance thermometer is placed will be heated in a small muffle and allowed to cool slowly. The recalescent point should be clearly shown on the cooling record.

*Thermo-Electric Thermometers.*—The couples exhibited are platinum-platinum 10 per cent. iridium and platinum-platinum 10 per cent. rhodium. The direct reading instrument (Fig. 3) consists of a sensitive D'Arsonval Galvanometer, the coil of which carries a pointer reading on a scale divided in degrees Centigrade. By means of a simple switchboard several thermo-couples can be connected in turn with the galvanometer. As explained above, the Callendar Recorder can be used to record the temperatures obtained with thermo-electric couples.

### THE LE CHATELIER PYROMETER.

Made by W. C. HERÆUS, Hanau, Germany.

At the instance of the Royal Physical Technical Institute at Charlottenburg, Mr. W. C. Heræus, of the well-known firm of platinum refiners at Hanau, undertook the manufacture of a pyrometer according to the principle of Professor Le Chatelier

of Paris. The principle involved is the conversion of heat into an electric current and the determination of the degree of heat by a suitable device indicating the electro-motive force of such a current.

A decided advantage which this pyrometer possesses over all others consists in its ease of application and convenience in handling, and in the fact that the temperature can be read off at almost any distance from the source of heat. The following

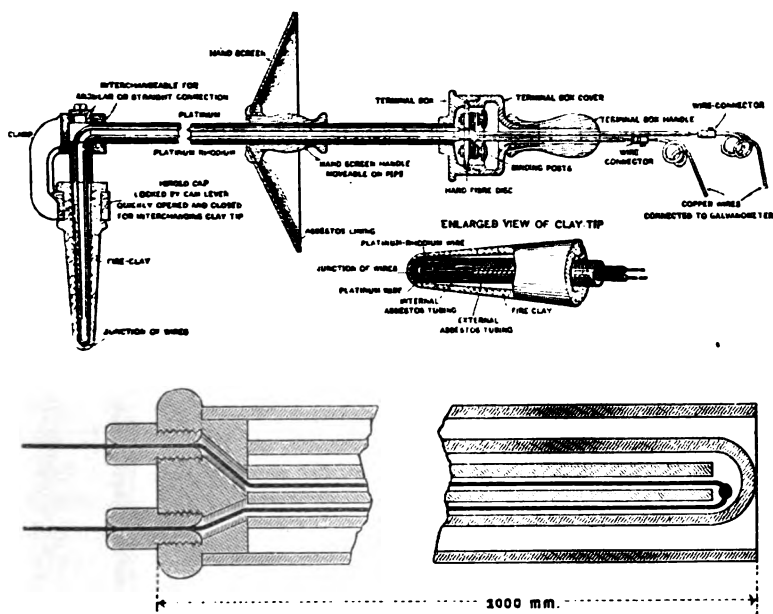


FIG. 5.

is a description of the apparatus and of the method of operation:—

Two wires, one of absolutely pure platinum, and the other consisting of the same metal alloyed with 10 per cent. of rhodium, are fused together at one of their ends in the shape of a small ball (Fig. 5), and thus form a couple. This ball generates a slight electric current when heated, and, as ascertained by the Royal Physical Institute by comparison with their celebrated air thermometer, such currents are proportional to the heat applied.

Each couple is accompanied by a table of results determined in the same manner.

To prevent injury to the wires by abrasion, injurious gases, and by alloying with other metals, they are usually enclosed in porcelain tubes, a small tube open at both ends being used to insulate the two wires, and a larger one, closed at one end, covering the whole. The Royal Porcelain Factory at Berlin

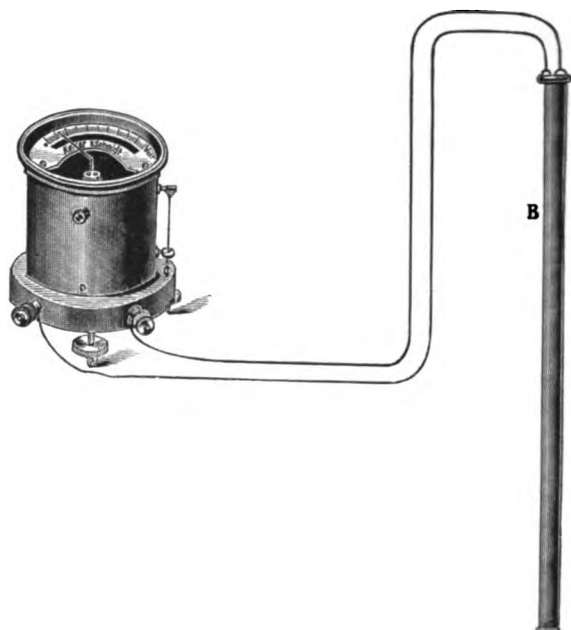


FIG. 6.

prepares such tubes from an extremely refractory porcelain base, which resists a temperature of  $2920^{\circ}$  Fahr. or  $1600^{\circ}$  C. These tubes can be made up to 50 inches in length.

The galvanometer used in connection with the pyrometer is of the D'Arsonval type, and is especially adapted to the measuring of thermo-currents. The current is transmitted to an armature, wound in quadrangular shape, through a fine wire of hard metal which does not oxidise. A small spring of the same material acts as a negative. A strong permanent magnet with

iron pole shoes constitutes a magnetic field, and an iron cylinder in the centre concentrates the magnetic lines of force. The pointer moves over two scales, one of which denotes the electromotive force of the current in micro-volts, thus making it possible to check the readings of the instrument, while the second scale gives direct readings of the degrees of temperature. On the side of the cylindrical casing of each instrument there is provided an adjustable thumb-screw, which secures the armature, thus avoiding the breaking of its delicate suspension wire while in transit. This screw should always be carefully secured before moving the instrument.

Adjusting screws in the base allow the instrument to be placed readily in a horizontal position, and a switch on the base of the galvanometer serves for the purpose of breaking the thermo-current. The wire clamp-screws on the galvanometer are marked + and - respectively. The clamp marked + should be connected to the platinum-rhodium wire and the one marked - to the platinum wire. The platinum is the softer one of the two ends. The knob at the upper end of the cylindrical casing is connected to the scales and permits their adjustment, or, indirectly, an adjustment of the pointer to the zero mark. From the above description the method of the application of the apparatus will be easily understood.

The end of the tube containing the two wires is exposed to the temperature to be measured, and the free ends of the wires are connected to the binding posts on the galvanometer (see Fig. 6). Or, if desired, the galvanometer may be placed at any distance from the element, and insulated copper wires may be used to connect both. This wire should be No. 12 American, or Brown & Sharpe Gauge for a distance of 300 feet, or for any distance the resistance of the wire used should be no more than one ohm.

As soon as the temperature of the thermo-element has risen to that of its surroundings, the deflection of the pointer along the scales will cease. The temperature surrounding the junction of the element wires with the copper conductors should be 32° Fahrenheit to give correct readings. Small variations therefrom, up to 65° Fahrenheit, for instance, will scarcely be significant for the application of the pyrometer in ordinary practice. However,

it is essential to keep the cold junction of the thermo-couple at freezing-point, if it is necessary to determine the **exact** temperature of a furnace or other source of heat by direct readings of a galvanometer. The successful application of this instrument in practice requires in some cases special contrivances (see Fig. 5), in order to adapt it to the various purposes it is intended for. The galvanometer dial represents the relation between degrees of temperature and millivolts.

### THE MESURÉ AND NOUËL OPTICAL PYROMETER.\*

Made by E. DUCRETET, Paris.

Messrs. Mesuré and Rouel have devised an indirect optical method of determining the temperature of heated masses of metal. In this method, which has been employed at the St. Jacques Steelworks at Montluçon, an instrument is used which is practically a polariscope (Fig. 8) arranged for plane polarised light, having a section of a quartz crystal (Q, Fig. 7) cut perpendicularly

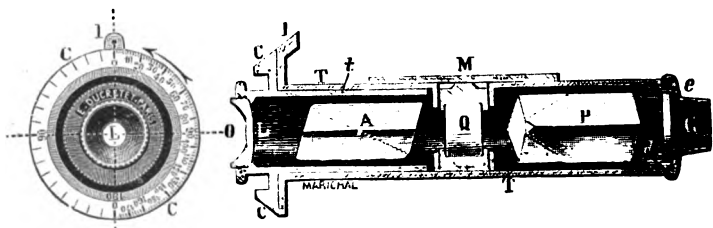


FIG. 7.

to the axis, interposed between the polarising and the analysing prisms (P and A, Fig. 7). In such a combination the plane of polarisation is turned by the quartz through an angle which varies directly as the thickness of the quartz plate, and approximately inversely as the wave-length of the light, or the rotation is larger for the shorter and more refrangible rays at the blue end of the spectrum than for those of the red end. As, however, the proportion of blue light becomes greater with increase of heat, it is evident that the angular deviation of the plane of

\* Compiled from Phillips and Bauerman's "Elements of Metallurgy," 3rd ed., 1891, p. 27, and *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1890, p. 129.

polarisation may be used as a means of comparing the temperatures of luminous bodies. The quartz section used is nearly half an inch (11 millimetres) thick, with which a rotation of  $4^{\circ}$  to  $7^{\circ}$  of arc is produced by each increase of  $100^{\circ}$  of heat.

The following table gives the number of degrees on the scale of the instrument, corresponding to the luminous tints as defined by the Pouillet scale—

Nascent cherry red	800° C., corresponds to an angle of	33 degrees.
Cherry red	900 " " "	40 "
Bright cherry red	1000 " " "	46 "
Yellow orange	1100 " " "	52 "
Yellow	1200 " " "	57 "
Bright yellow	1300 " " "	62 "
White welding	1400 " " "	66 "
Dazzling white	1500 " " "	69 "
A temperature of	1600 " " "	71-72 "
" "	1700 " " "	73-74 "
Solar light	" " "	84 "

For these high temperatures the melting-point of platinum and that of silver were taken as the standards, the figures given by Professor Violle being  $1775^{\circ}$  C. and  $954^{\circ}$  C. respectively.

For the lower temperatures, where the light is feeble, a condensing lens (L, Fig. 7) is used, to concentrate the beam for the polariser, but no useful indication can be obtained at a dull red heat. The rotation in bright sunlight is  $84^{\circ}$ .

At the higher temperatures the sensitive or passage tint marking the position of extinction is similar to that in sunlight, namely, a neutral purple, which becomes blue or red by a very small rotation of the analyser in one or other direction; but for the duller red and yellow heats the passage is a greyish yellow, changing to green or red. The value of the instrument is less as an absolute measurer of temperature than as affording a rapid means of reproducing similar conditions when a number of ingots or forgings have to be brought exactly to the same heat. Care must be taken in using it that the light observed is actually that given off by the heated mass, and that it is not increased by reflections from flame, or more highly incandescent surfaces, whereby the results obtained would be too high.

When observing temperatures below  $900^{\circ}$  C., it is necessary to fix a large lens in front of the optical tube, in order to concentrate a large number of rays.



It is often required to gauge the temperature of various metals which, during fusion, give off coloured vapours which impede the observation of the tints as they come and go. This difficulty is obviated by plunging an iron tube (Fig. 9), closed at one end, into the bath. The closed end is immersed, and by applying the optical pyrometer to the open end, the bottom of the iron tube can be observed without interruption.

When the substance under examination is of low conductivity

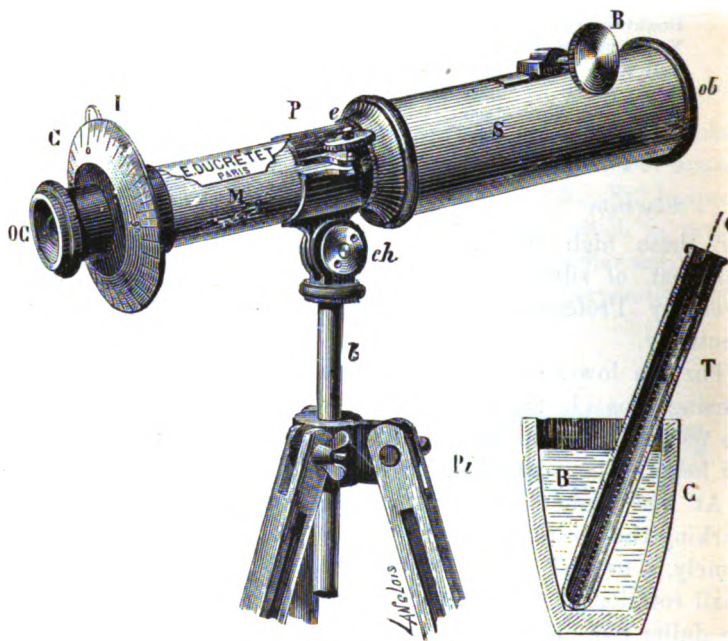


FIG. 8.

FIG. 9.

the luminosity diminishes very rapidly in cooling, and therefore observations made on substances after withdrawal from the furnace must be made as quickly as possible.

#### THE ROBERTS-AUSTEN RECORDING ELECTRIC PYROMETER.

Made by Messrs. JAMES PITKIN & Co., London.

This instrument, which is of the recording electrical type, was devised by the late Sir William Roberts-Austen for the con-

tinuous registration of very high temperatures, and it is widely used for recording the temperature of the hot-blast, and for regulating the heat of metallurgical furnaces.

The general form of the apparatus is shown in Fig. 10, and may be described as consisting of two mahogany cases impervious to light, the larger of which (A) contains a Holden d'Arsonval dead-beat galvanometer, with a suitable arrangement of lenses and mirrors. The other case (B) contains a drum which is made to revolve by clockwork once in twenty-four, twelve, or six hours. The surface of this

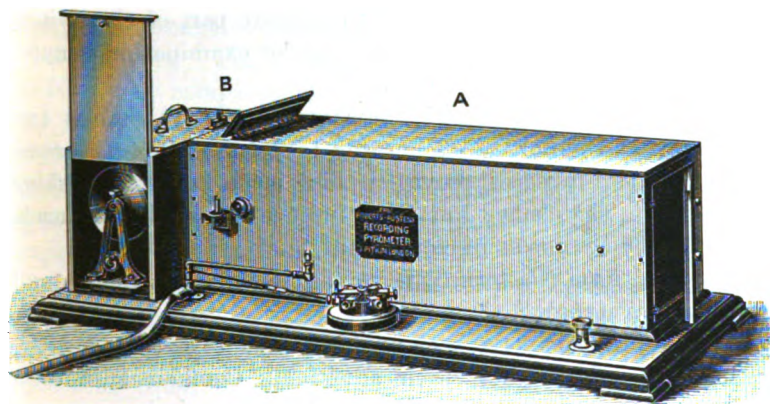


FIG. 10.

drum may be covered with sensitised photographic paper. A ray of light, either from a gas jet or from a lamp, is thrown by means of a mirror at an angle of  $45^\circ$  on to the mirror of the galvanometer, and is projected thence to the surface of the drum, acting photographically on the sensitised paper. The galvanometer is then connected by copper leads to a thermo-junction inserted in the space or object, the temperature of which it is desired to record. The thermo-junction may, for example, be placed in a hot-blast main, or in the midst of a small mass of metal which is either being cooled from a high temperature or is being raised to a temperature below that of the melting-point of platinum. The heating of the thermo-junction causes a very small current to pass through the coil of the galvanometer, which

is deflected, and the mirror attached to it projects a spot of light on the surface of the drum. The amplitude of this deflection indicates the temperature, and a continuous curve is traced on the photographic paper, which at once indicates what temperature is attained at any particular moment. A scale is also provided on which the temperatures can be read from time to time, without interfering in any way with the record.

The most simple of the standard forms (Pattern 1) is provided with a simple switch or handle, by means of which a record from any one of six furnaces or centres of heat may be obtained. The time devoted to the record of any of the six depends upon the length of time the handle is left at a definite part of the switch. The number of the particular furnace under examination is automatically registered on the drum.

The second form of the instrument (Pattern 2) enables two continuous and simultaneous records to be taken on the same drum from two furnaces, provision being made for distinguishing the curves. The change from one furnace to another is made automatically by means of clockwork.

The third form (Pattern 3) is for taking three continuous and simultaneous records.

Thermo-junctions have been used from time to time since 1826, when Becquerel advocated their adoption. Confidence in their indications was, however, only established when it became possible to obtain a good dead-beat galvanometer. The particular thermo-junctions to be used will vary with circumstances, and for many purposes the platinum-platinum-*iridium* junction, first used by Professor Tate in 1873, possesses many advantages over other thermo-junctions.

Specially designed electric recording pyrometers are also constructed by the same makers for research work, similar to those used at the Royal Mint, where extreme accuracy is required in determining temperatures. In this pattern two galvanometers are employed, one of greater sensitiveness than the other, in a case impervious to light. A ray of light either from a gas jet or from a lamp, is thrown, by means of a mirror at  $45^\circ$  (having been focussed by suitable lenses), on to the galvanometer mirrors, and is projected thence on to the surface of a photographic plate. This plate is raised at any desired speed by means of an accurately-

constructed clockwork train, and the rays of light from the galvanometer mirrors, reduced by means of a horizontal slot to mere points of light, fall on to the sensitised surface, which, being developed, gives an accurate record of the temperature at every instant of time. A dark slide or plate-carrier is provided for enclosing the plate, to enable it to be removed to the dark room for development.

### THE ROSENHAIN-CHALMERS OPTICAL PYROMETER.

Made by THE CAMBRIDGE SCIENTIFIC INSTRUMENT Co., Limited, Cambridge.

This instrument has been constructed to the general designs of Mr. W. Rosenhain, the optical system being designed by Mr. S. D. Chalmers. The instrument measures the temperature of a hot body by comparing the intensity of light given out by the body with the intensity of the light given out by a comparison body of known temperature. The comparison body employed is a fine wire of platinum, and the comparison is effected by forming an image of the hot body in the focus of a small telescope, the comparison wire being also fixed in that focus. The fine wire is heated by means of a small electric current from an accumulator, and this current is regulated by means of a suitable resistance until the fine wire as seen in the field of the telescope appears of equal brightness with the image of the hot body. The comparison is readily made, since the wire and image are superposed, and are of practically the same colour. When equal brightness has been attained, the current passing, and consequently the temperature, can be read off directly from the delicate ampère meter provided. By this process of direct comparison temperatures up to about  $1200^{\circ}$  C. are readily determined; above that temperature the intensity of the light becomes too great for delicate comparison, and dark or coloured glasses are interposed. When it is required to determine very high temperatures, near to or above the melting-point of platinum, the instrument is modified by cutting off any desired proportion of the light from the hot body by means of one of the sector stops provided. The sector stops are used in order to avoid interfering with the aperture ratios of the optical system, since these are specially arranged so as to make the readings of the instrument independent of the distance from the hot body at which it may be erected.

When the sector stops are used, the temperature corresponding to any given current in the hot wire will, of course, be different from that indicated when the full aperture is used, so that the ampère meter must be supplied with two or more temperature scales to accord with the stops it is desired to use. Further, when the sector stops are in use, the actual temperature of the body under observation will differ materially from that of the comparison wire, so that the advantage of similar colour will be partly lost; consequently observation through ruby glass is preferable under those circumstances.

The temperature scales of the instrument are, in either case, obtained by calibration against a body of known temperature, which should either be a black body or a heated space, such as a furnace, observed through a small aperture in one wall.

The special advantages afforded by this instrument are the following: it is portable, quick in action, and capable of considerable accuracy, many of the difficulties of the older photometric pyrometers being avoided. It is independent in its indications, within wide limits of the distance separating it from the object under observation. It thus becomes possible to follow hot metal, either in the casting-ladle or under hammer or rolls, making frequent observations of its surface temperature. The measurement of the temperature of moving objects is rendered possible by the absence of any mechanical contacts between portions of the instrument and bodies under observation, and this condition also renders possible measurement of temperatures above the melting-point of platinum. The instrument is economical in use, since there are no platinum parts exposed to furnace heat or gases, while the fine resistance wire can be readily replaced. On these grounds, the special applicability of the instrument to metallurgical purposes is evident.

### THE SEGER CONES.

Made by Dr. H. SEGER and E. CRAMER, Berlin.

Segeer cones consist of a series of truncated, pyramidal-shaped bodies composed of a graduated mixture of aluminium silicates, which soften and fuse at definite temperatures, and by the

aid of which it is possible to determine the approximate temperatures of furnaces and of heated spaces. The following table gives the numbers of the series which are employed in practice, together with the approximate temperatures at which they fuse :—

No.	Temp. in Degrees C.	No.	Temp. in Degrees C.	No.	Temp. in Degrees C.
022	590	03	1090	17	1470
021	620	02	1110	18	1490
020	650	01	1130	19	1510
019	680	1	1150	20	1530
018	710	2	1170	21	1550
017	740	3	1190	22	1570
016	770	4	1210	23	1590
015	800	5	1230	24	1610
014	830	6	1250	25	1630
013	860	7	1270	26	1650
012	890	8	1290	27	1670
011	920	9	1310	28	1690
010	950	10	1330	29	1710
09	970	11	1350	30	1730
08	990	12	1370	31	1750
07	1010	13	1390	32	1770
06	1030	14	1410	33	1790
05	1050	15	1430	34	1810
04	1070	16	1450	35	1830
				36	1850

It must be strictly understood that the above figures are only an approximation to reality. Thus all that can really be said safely is that No. 022 fuses at a dull red heat; No. 010 at the melting point of silver; No. 1 in the vicinity of that of an alloy of 90 per cent. of gold and 10 per cent. of platinum; No. 10 yields at a point where a similar cone of felspar would commence to soften; and No. 36 corresponds roughly to the melting point of platinum, the intermediate cones being interpolated in the series. Even this approximation is sufficiently correct for numerous industries. By standardising a number of intermediate cones by means of the Le Chatelier thermo-electric pyrometer, and by definitely determining the softening points of the most readily fusible and of the most refractory cones respectively, and the values, in degrees centigrade, of Nos. 010 and 1, and adjusting the remainder by interpolation, a series is obtained which, assuming the incremental variations to be correctly expressible as constants, will at least furnish a useful indication

of temperature, although not, of course, by any means a definite or accurate determination. In practice a number of cones are placed in the furnace, ranging over perhaps 8 or 10 Nos. in sequence. On the conclusion of the experiment the cones are found variously affected, some having completely collapsed, while others are hardly altered. The temperature is taken to be that at which a particular cone in the series appears to present a mean degree of fusing.

In order to facilitate the introduction of the cones into the furnace, a sort of muffle made of fire clay is employed, in which the cones are placed. This can be withdrawn from the furnace or oven, from time to time, for inspection. Workmen who are in the habit of using these cones are accustomed to describe the temperature of an oven in terms of the number of the cone which is observed to soften at that temperature. In practice, however, their use is chiefly confined to brick and tile ovens, or to the kilns used for firing pottery and porcelain.

The composition of the cones is quartz, kaolin, white marble, and felspar, the raw materials used for glazes at the Royal Berlin Factory. The price of the cones is 4s. 6d. per dozen, and the muffles in which they are placed cost 2s. each.

### THE SIEMENS ELECTRIC PYROMETER.

Made by Messrs. SIEMENS BROTHERS & Co., Limited, London.

The Siemens Electrical Pyrometer is a platinum resistance thermometer which has a coil of platinum wire wound upon a cylinder of refractory material and fixed, usually, at the end of a long closed iron tube where it is protected by a platinum shield. To measure, in actual practice, the resistance of the coil and thus its temperature, two types of apparatus are employed. One of these, comprising a differential galvanometer and a set of resistance coils, gives readings in ohms, from which the temperatures are ascertained by means of special tables. The other is a combination of a small D'Arsonval galvanometer and a Wheatstone bridge of circular form with sliding contact, and gives readings directly in thermometric degrees.

The first of these types is an instrument of great accuracy, and its determinations can be relied upon to agree within a fraction of 1 per cent. with those of an air thermometer. It is very simple in its arrangement and working, and may be entrusted to the care of any intelligent workman. It finds special application in works where it is necessary to ascertain from time to time the heat of furnaces, flues, &c., particularly those in which the processes demand the maintenance of a definite temperature during certain operations. It is employed in most of the principal steel works in the United Kingdom and on the Continent

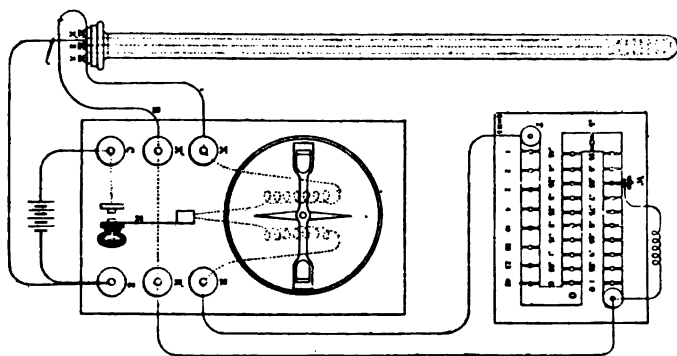


FIG. 11.

for determining temperatures during the manufacture of steel plates.

Fig. 11 is a diagram showing the pyrometer and galvanometer with resistance coils and battery connected up for taking a reading. The galvanometer is placed with its needle pointing to zero and the end of the pyrometer tube is inserted in the furnace the temperature of which is to be measured, the upper part of the tube being protected from the heat by fireclay or a sheet of iron. When the tube is thought to have acquired the temperature of the furnace, the key marked K is pressed down, causing the battery current to divide at the back of the key into two circuits, one of which includes one coil of the galvanometer and the pyrometer coil, while the other includes the other galvanometer coil and the resistance box. If the resistance of the pyrometer



coil does not equal that of the circuit of the resistance box, the needle is deflected, and in order to establish a balance the holes in the resistance boxes must be plugged or unplugged, until the galvanometer needle returns to zero. The sum of the unplugged whole numbers of the resistance box, plus the decimal marked opposite the hole filled by the travelling peg, will then give the resistance of the pyrometer coil in ohms.

In order to take a reading, the travelling peg connected with the terminal  $R^1$  is inserted in the hole marked  $o$ , and the resistance between the fixed terminals  $T$  and  $o$  is unplugged until the galvanometer is balanced as nearly as possible, while the key  $K$  is continuously depressed. The travelling peg is then moved along the decimal coils of the resistance box until the point is reached when the galvanometer needle remains exactly at zero and the unplugged resistance between terminals  $T$  and  $o$  is then read off plus the decimal indicated by the travelling peg. The resistances between the terminals  $T$  and  $o$  are additive, while the decimal parts progress by 0.05 ohm from 0 to 1 ohm. Thus, if the holes 1, 2, 4, and 20 are unplugged, and the travelling peg is in the 0.65 hole, the resistance of the coil will be 27.65 ohms. The length of the wires  $A$  and  $B$  connecting the galvanometer to the pyrometer tube does not affect the reading so long as the wires are of equal resistance, as their resistances vary equally with variations of temperature and balance one another.

The second type, or Direct Reading apparatus, comprises a Wheatstone bridge, one limb of which is an adjustable resistance formed out of a helical coil of wire arranged round the edge of a circular dial. The dial is divided into either Fahrenheit or Centigrade degrees as desired, and in the centre of it is a small D'Arsonval galvanometer, a type of instrument unaffected by external magnetic fields. A sliding contact with a pointer serves to adjust the resistance of the variable limb of the bridge, and at the same time to indicate on the dial the temperature of the coil when the balance has been obtained. The keys are combined and fitted to the arm of the sliding contact in such a way that by depressing the knob of the contact the battery is put into circuit with the galvanometer and pyrometer. The whole is mounted upon a tripod stand. (See Fig. 12.)

To take a temperature the pyrometer is connected by means of a three-cored cable to three of the terminals and the battery

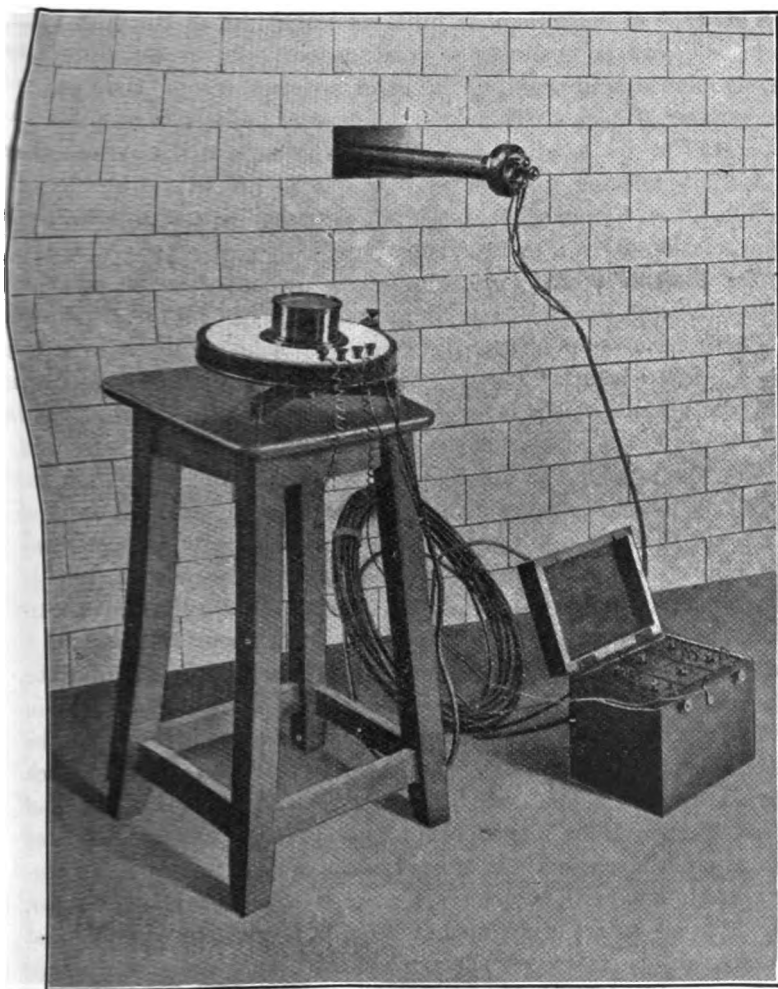


FIG. 12.

to two terminals of the instrument, as shown in Fig. 12. The sliding arm is moved to some point on the scale and the lever depressed until the point is found at which depression of the

key produces no deflection of the needle of the galvanometer. The pointer attached to the sliding contact will then indicate the temperature of the pyrometer coil.

This type of instrument is quite as sensitive as the first type described, and it possesses a great advantage in avoiding the inconvenience and liability to error arising from the use of Conversion Tables. There is, moreover, only one piece of apparatus to be handled, instead of two, and, unlike the other, it is not affected by external magnetic fields due to the proximity of dynamos or powerful electric currents, while its manipulation is even more simple.

*The Siemens Water Pyrometer.*—The pyrometer is shown in cross-section in the accompanying sketches (Fig. 13). It consists of a cylindrical copper vessel provided with a handle, and containing a second smaller copper vessel. An air space *a* separates the two vessels, and a layer of felt surrounds the inner one, in order to retard the exchange of temperature with the surroundings. The capacity of the inner vessel is a little more than one pint. A mercury thermometer *b* is fixed close to the wall of the inner vessel, its lower part being protected by a perforated brass tube, whilst the upper projects above the vessel and is divided as usual on the stem into degrees, Fahrenheit or Centigrade, as desired. At the side of the thermometer there is a small brass scale *c*, which slides up and down, on which the high temperatures are marked in the same degrees as those in which the mercury thermometer is divided; on a level with the zero division of the brass scale a small pointer is fixed, which traverses the scale of the thermometer. Short cylinders *d*, of either copper, iron, nickel, or platinum, which are so adjusted that their heat capacity at ordinary temperature is equal to one-fiftieth of that of the copper vessel filled with one pint of water, are supplied with the pyrometer. As, however, the specific heat of metals increases with the temperature, allowance is made on the brass sliding scales, which are divided according to the metal used for the pyrometer cylinders *d*. It will therefore be understood that a different sliding scale is required for the particular kind of metal of which a cylinder is composed. In order to obtain accurate measurements, each sliding scale must be used only in conjunction with its own thermometer.

The water pyrometer is to be used as follows:—

Exactly one pint (0·568 litre) of clean water, preferably dis-

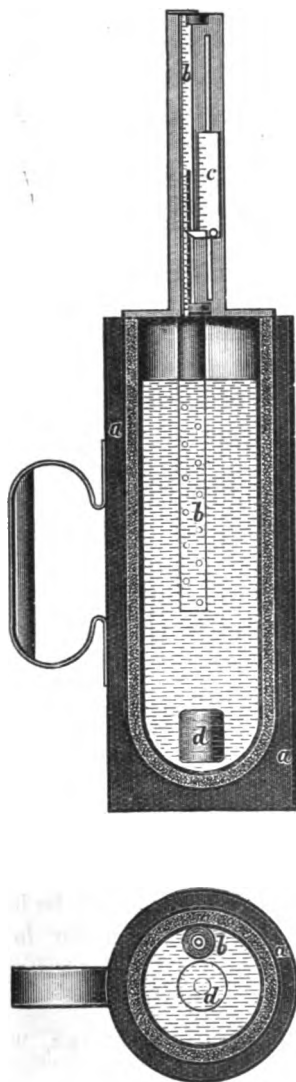


FIG. 13.

tilled or rain water, is poured into the copper vessel, and the pyrometer is left for a few minutes to allow the thermometer to

attain the temperature of the water. The brass scale *c* is then set with its pointer opposite the temperature of the water as shown by the thermometer. Meanwhile one of the metal cylinders has been exposed to the high temperature which is to be measured, and after allowing sufficient time for it to acquire that temperature, it is rapidly withdrawn and dropped into the pyrometer vessel without splashing any water over. The temperature of the water then rises, and when the mercury of the thermometer has become stationary the degrees are read off, as well as those on the brass scale opposite the top of the mercury. The sum of these two values gives the temperature of the heated space in which the metal cylinder has been placed. With cylinders of iron or copper temperatures up to 1800° Fahr. or 1000° C. can be measured, but with platinum cylinders the range is up to 2700° Fahr. or 1500° C. For ordinary furnace work either copper or wrought iron cylinders may be used. Iron possesses a higher melting-point and has less tendency to scale than copper, but the latter is affected much less by the action of the furnace gases. Nickel is available for temperatures up to 1400° C., and possesses superior advantages in freedom from scaling or from attack by the gases. Platinum is of course not subject to any of these disadvantages. The weight to which the metal cylinders are adjusted is as follows :—

Copper . . . . .	137 grammes
Wrought iron . . . . .	112 ..
Nickel . . . . .	117 ..
Platinum . . . . .	402·6 ..

In course of time the copper cylinders lose weight by scaling, but a table is supplied giving the percentages by which the readings on the brass scale alone are to be increased before being added to the degrees of the thermometer in order to obtain the correct temperature.

#### THE UEHLING PNEUMATIC PYROMETER, WITH AUTOGRAPHIC RECORDER.

By JOS. H. HARRISON, M.Inst.C.E. (Middlesbrough).

The Uehling Pneumatic Pyrometer and the Steinbart Automatic Recorder form one complete instrument, the former registering

the temperatures attained, and the latter at the same moment legibly recording them in ink. It has already been adopted in this country to a very considerable extent in large iron and steel works, and is used almost exclusively in such works in America, which is its home.

The Uehling pyrometer, although of the pneumatic type, is not based, as some are, upon the varying pressure of enclosed air heated to the temperature to be measured, but upon the laws governing the flow of air through small apertures. The diagrammatic view, Fig. 14, shows the principle upon which the instrument

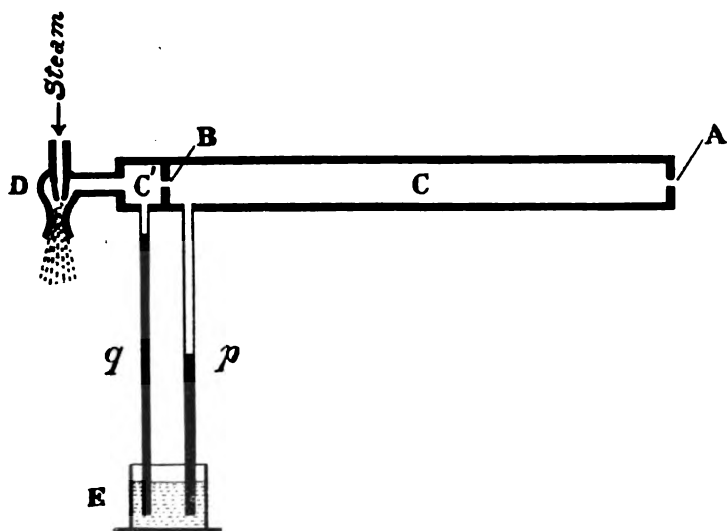


FIG. 14.

works. The chamber *C* has an inlet aperture *A*, and an outlet aperture *B*, and a uniform suction is created in the chamber *C'* by the steam aspirator *D*. Air will be drawn into chamber *C'*, creating suction in chamber *C*, which in turn causes air to enter through aperture *A*. The velocity at which the air flows through *A* depends upon the suction in *C*, and the velocity at which it flows through *B* depends upon the excess of suction in *C'* over that in *C*, that is, the effective suction in *C'*.

As the suction in *C* increases, the effective suction in *C'* must decrease, and hence the velocity at which air flows in through *A*

increases, and the velocity at which air flows out through B decreases, until the velocity of flow through both apertures becomes equal. When this occurs, no further change of suction in C will take place. Air is expanded by heat, therefore the higher its temperature the greater its volume, and consequently the smaller will be the quantity drawn through a given aperture by the same suction after it has been reduced again to normal temperature. If, therefore, the atmospheric air before entering A is heated and again cooled to some lower temperature, say 212° F., before passing through B, less air will enter through A than is drawn out through B, hence the suction in C must increase and the effective suction in C' decrease, therefore the velocity of the air through A will increase and that through B will decrease until again the same quantity of air flows through each aperture. Thus every change in temperature of the air entering through the aperture A will cause a corresponding change of suction in chamber C, and therefore these changes of suction in C represent truly the changes of temperature of the air entering aperture A. Two manometer tubes, *p* and *q* (Fig. 14), communicate respectively with the chambers C and C', the lower ends being immersed in water. The column in tube *q* will indicate the constant suction in C', and the column in tube *p* will indicate the suction in the chamber C, which suction is a true measure of the temperature of the air entering aperture A.

In order to construct an instrument based upon the above principle, it is obvious that certain very exacting conditions must be fulfilled continuously, and with certainty. These are:—

1. The air must be drawn through these apertures with a perfectly uniform suction.
2. The aperture A must be located in such a position that the air entering it shall have acquired the same temperature as that to be measured.
3. The parts exposed to the heat must be constructed of a material which will resist the highest temperature to be determined, and also will not scale.
4. The aperture B must be located in a medium of perfectly constant and fixed temperature.
5. Provision must be made that the apertures remain perfectly clean and free from scale.

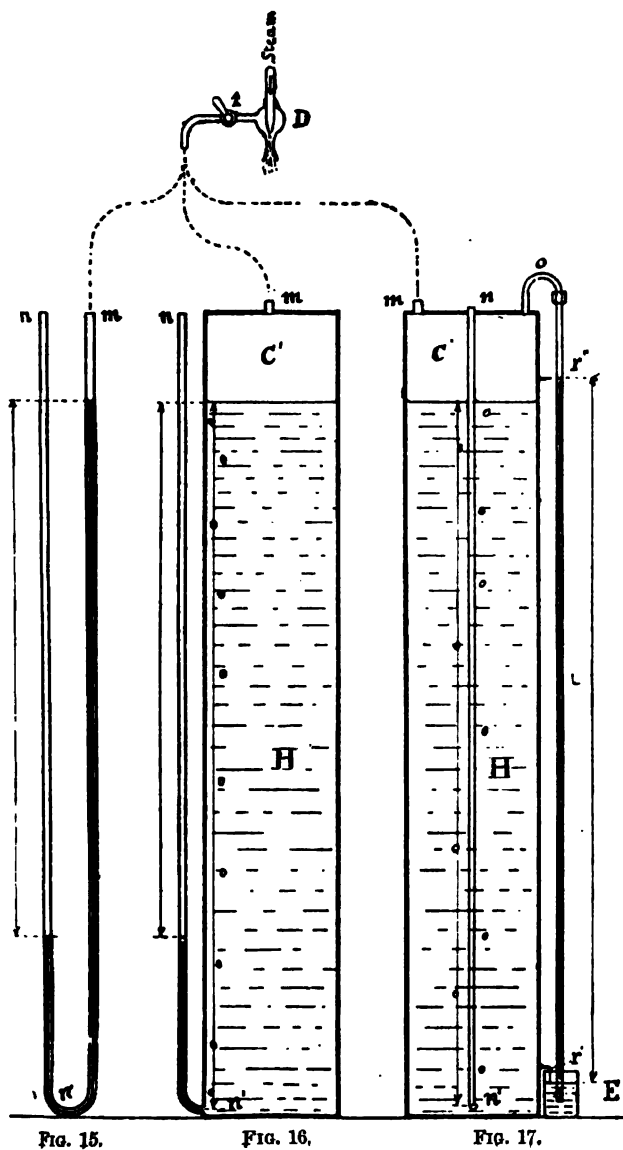


FIG. 15.

FIG. 16.

FIG. 17.



6. The chamber C must be absolutely air-tight, so that no air can enter except through aperture A.

The above conditions are fulfilled in the following manner :—

1. A small steam aspirator working in conjunction with a suction regulator provides uniform suction, and the suction regulator H (Fig. 17) works on the principle of sucking air through a constant column of water.

If we take a "U" tube (Fig. 15) partly filled with water, and apply suction at one end, the water will rise in that leg and fall in the other, and the difference in levels will be a measure of the suction applied. If we enlarge the leg to which the suction is applied to many times the diameter of the other leg, as H (Fig. 16), the water will fall in the smaller leg the same as before, but it will rise only very slightly indeed in the larger leg. Still, the difference between the water levels is just as true a measure of the suction applied as before. If the suction is increased in C', the water in the smaller leg *n* falls still lower, until eventually all the water it contained has passed into H. By continuing the suction, air will be drawn down *n*, and bubble up through the water in H to chamber C'. No further increase in suction can be obtained in chamber C', because it is being satisfied by air entering through *n* as fast as it can be drawn away by the aspirator from C'. The height of the water-level in H, above the point *n'* where air enters from *n*, is again a true measure of the amount of suction applied.

If we now assume that the small leg is put down inside the larger one (Fig. 17), the bottom end being left open at the same level as that at which it previously joined the larger leg, and suction be applied again at the top of C', it is clear the same conditions will be brought about, the water being drawn out of the tube *n* until air is drawn through as before, thus limiting the suction. The height of the water-level in H above the bottom of the tube *n* will still be a measure of the amount of suction in C'. If a glass tube be connected from the top of the chamber C', and carried down the outside of the larger leg H, the lower open end dipping into a jar of water (Fig. 17), the water will rise in this tube until the height from the water-level in the jar to that in the tube is exactly the same as that from the water-level in H to the bottom of tube *n*, and will therefore

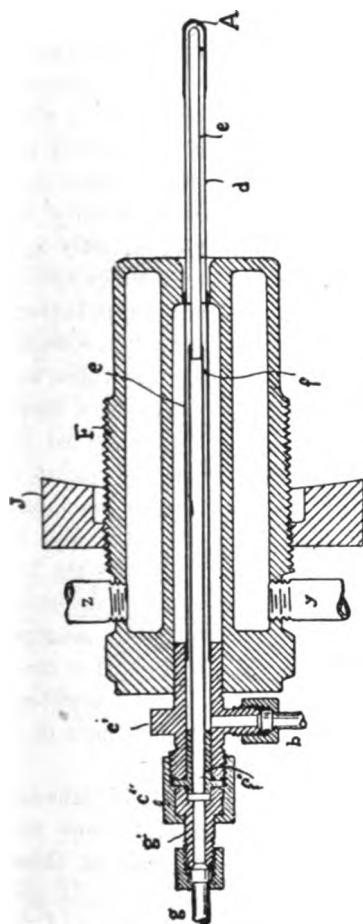


FIG. 18.

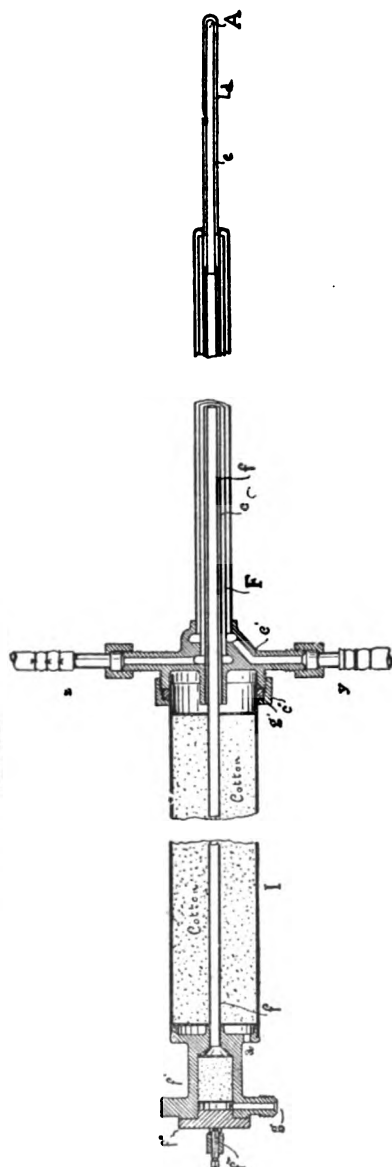


FIG. 19.

form an index of the height of the water in  $H$ , and of the suction in  $C'$ . This arrangement is known as the regulator, and by keeping the water-levels in  $H$  and the jar  $E$  at constant heights, a perfectly uniform suction is obtained, and thus fulfils condition 1.

*Fire Tube.*—Fig. 18 shows a fire tube which is suitable for a gas or hot-blast main of a blast-furnace, and is arranged to fulfil condition 2. The aperture  $A$  is made at the end of a small closed platinum tube  $e$ , enclosed within an outer tube of the same material  $d$ , so that the aperture is within a very short distance of the end of the tube  $d$ , which protects it. These platinum tubes  $d$  and  $e$  are brazed into drawn copper tubes  $c$  and  $f$ , which are cooled by the water jacket  $F$ . The tube  $c$  is soldered into the coupling-piece  $c'$ . The tube  $f$  terminates in a flanged head  $f'$ , and is screwed to the coupling-piece  $c'$  by the follower  $g'$  and the nut  $c''$ , thus making by knife-edge spigots a perfectly tight metal and metal joint between the inner and outer tubes  $f$  and  $c$ , which prevents any communication between them except through the aperture  $A$ . Atmospheric air enters by connection  $b$ , which opens into the space between the inner and outer tubes, and finds its way to aperture  $A$ . The fire tube is held by a neck in the water-cooled jacket  $F$ , which is continuously fed by water which enters at  $y$  and escapes at  $z$ . This water jacket is screwed into a flange bolted on to the blast or gas main, and protects those parts of the fire tube which would otherwise be injured by heat. It will thus be seen that by fixing the fire tube in such a position that the platinum point is in the hot-blast or gas, the temperature of which it is desired to measure, the air between the two platinum tubes will acquire that temperature before it enters the aperture  $A$ , and thus fulfil condition 2. Fig. 20 shows the fire tube fixed in a hot-blast main of a blast-furnace.

Condition 3 is provided for by making those parts of platinum which are exposed to the heat. The water jacket prevents the temperature rising to a point sufficient to form scale on those parts which it protects.

*Constant Temperature.*—Fig. 21 shows how condition 4 is fulfilled. The aperture  $B$  is made in a small dished platinum plate, which is held between knife-edge spigot joints in a small

brass casting located within a chamber G, and in connection with a copper coiled pipe *ii*. The steam aspirator exhausts into this chamber G, and the steam and condensed water escape through the drain-pipe *t* into the atmosphere. This chamber G is there-

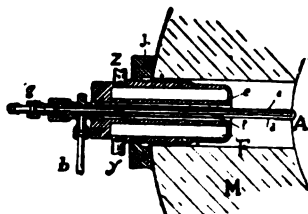


FIG. 20.

fore constantly maintained at a temperature of 212° F., and the air which has previously passed the aperture A in the fire tube in flowing through the coil-pipe *ii* acquires this temperature before passing through the aperture B, and thus condition 4 is fulfilled.

*Filter.*—Condition 5 is met by filtering the atmospheric air before it goes to the fire tube by means of the simple filter,

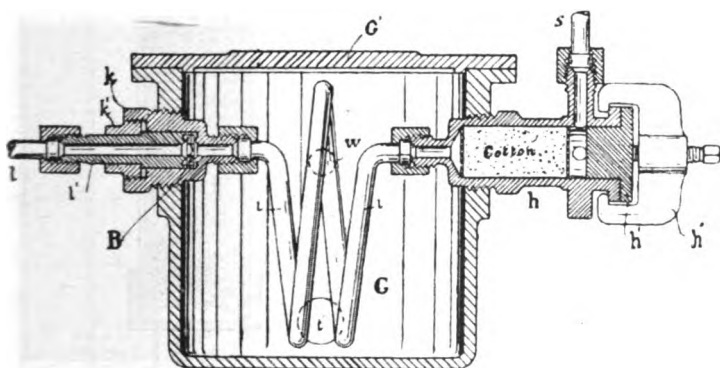


FIG. 21.

**Fig. 22.** This is a piece of 2-in. diameter pipe filled with cotton-wool having a hole *a* in the bottom cap and a cock 4 on the top cap, from which a drawn copper tube connects by knife-edge joints to the connection *b* on the fire tube.

*Air-tight Joints.*—To meet condition 6, the pipe from the fire tube to the regulator is of drawn copper, and all joints are made

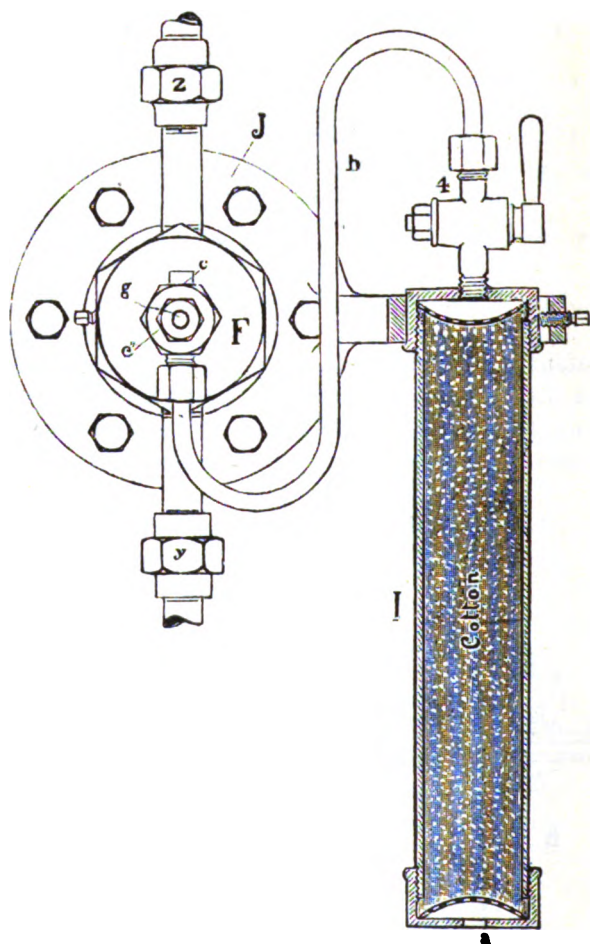


FIG. 22.

with knife edges of gun metal bearing against copper, metal and metal, which makes a perfectly tight joint.

A diagrammatic view of the principal details when assembled is given in Fig. 23. The interior of the pipe *e, f, g, h, i*, from

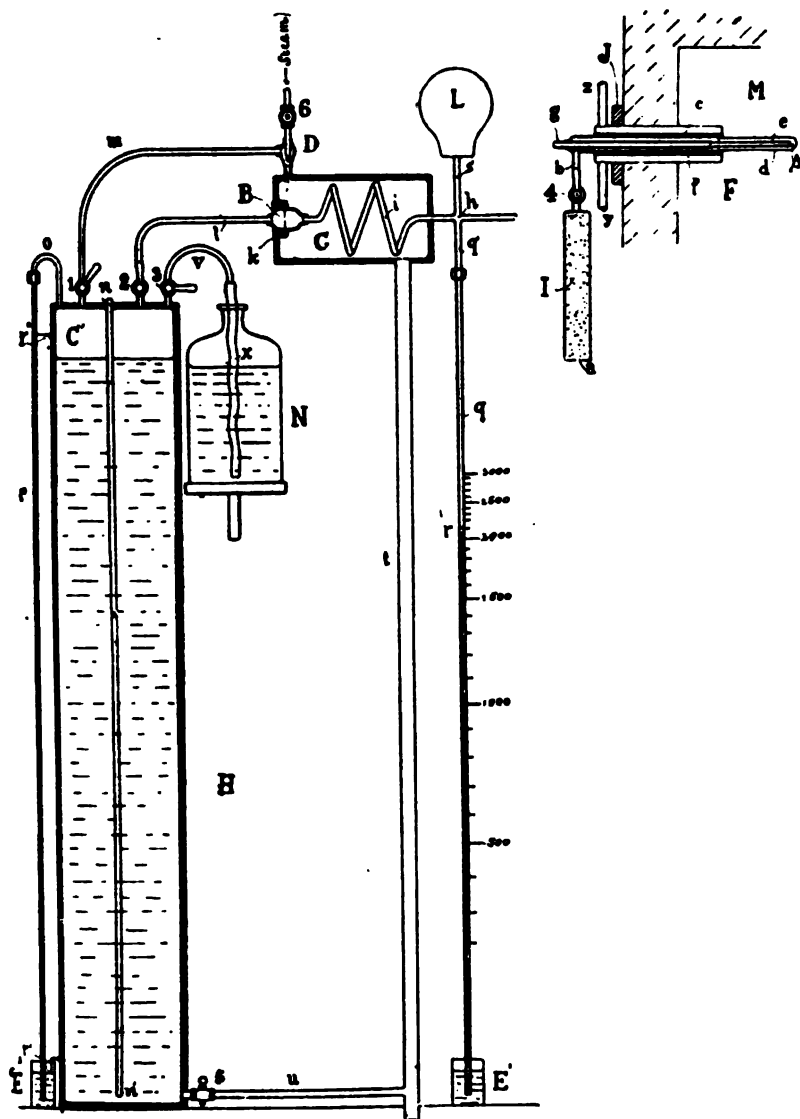


FIG. 23.

aperture to aperture, together with branches  $q'$  and  $s$ , forms the chamber C of Fig. 14. The inlet from the atmosphere is through the hole  $a$  in the bottom of filter I, and the connection to chamber C' is through the pipe  $l$ . The steam aspirator D sucks air through the tube  $m$  out of the chamber C' and produces a suction in C', which is kept constant by the regulator H, as already explained, and is shown by the manometer tube  $p$ . The steam from the aspirator is exhausted into the chamber G, keeping it at a constant temperature of  $212^{\circ}$  F., the steam and condensed water escaping through pipe  $t$  to the atmosphere. With a constant suction in C', and cocks 2 and 4 open, air will enter the filter I at  $a$ , where it is purified and passes through pipe  $b$  to fire tube. It flows in the annular space between the two tubes  $c$  and  $f$ , and as it reaches the point of the platinum fire tube  $d$ , which protrudes beyond the water jacket, it acquires the temperature surrounding it which is to be measured and passes in through the aperture A at that temperature. It then passes through the pipe  $e, f, g, h$  into the coil  $i$ , where it assumes the temperature of  $212^{\circ}$  F., at which it passes through the aperture B, thence by the pipe  $l$  into the chamber C', from which it is drawn by the aspirator D through  $m$  and discharged with the exhaust steam and water to the atmosphere again. The branch pipes  $s$  and  $q'$  connect respectively to the recording gauge L and the manometer tube  $q$ , which is placed on a graduated temperature scale.

The combination therefore fulfils all the conditions, viz. air is drawn through the instrument with a constant suction, and it passes through the aperture B at a constant temperature. Aperture A is so located that the air must enter it at the temperature to be measured. Hence the indications of the manometer tube  $q$  will vary with the temperature at A, and can be read off directly on the temperature scale placed beside it. Figs. 24, 25, and 26 illustrate this pyrometer as actually constructed for practical use. The same letters designate the same parts as in previous figures.

This pyrometer is made in either single or double form. The former serves one fire tube either fixed or portable, and the latter serves two fire tubes either fixed or portable. Figs. 24 and 25 show a single instrument. The latter figure is from a

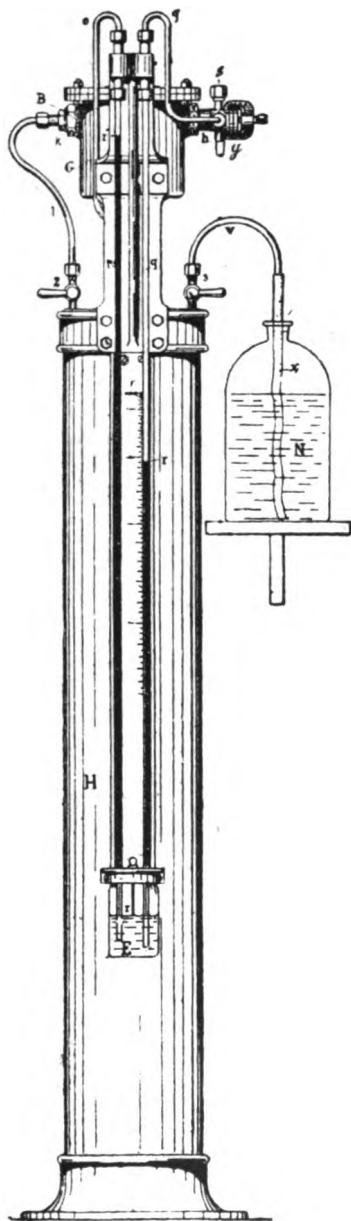


FIG. 24.



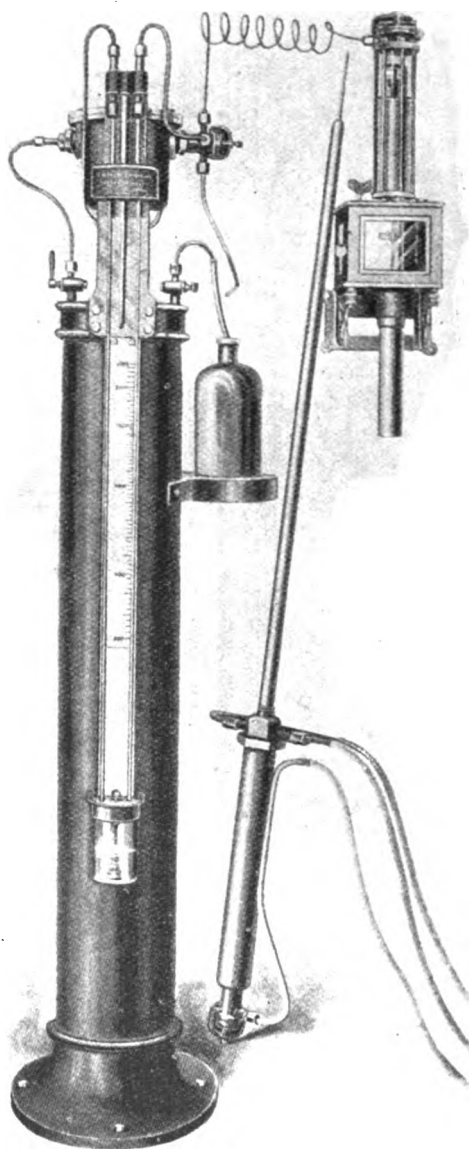


FIG. 25,

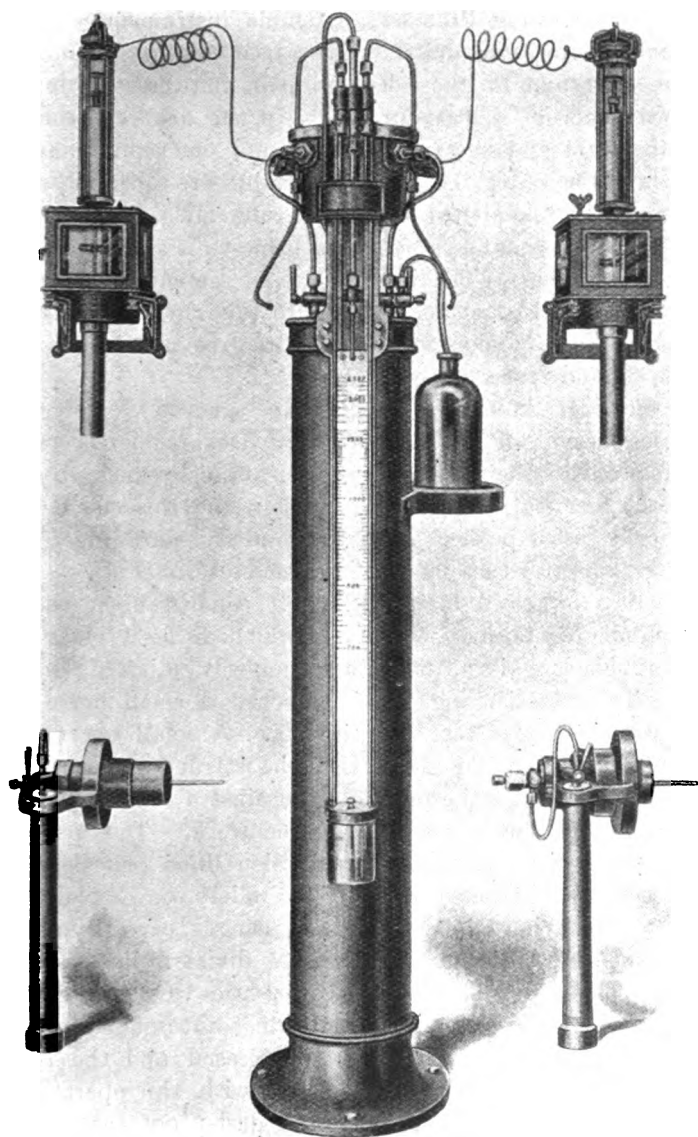


FIG. 26.

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photograph, and shows also a portable fire tube and a Steinbart recording gauge. Fig. 26 shows a double instrument. This is also from a photograph, and shows two recording gauges and two fixed fire tubes, one for the hot-blast main and the other for the gas down-comer of a blast-furnace. In the double pyrometer one temperature and suction regulator and one aspirator serves the two fire tubes. Fig. 19 shows a portable fire tube with water jacket and filter combined for use in annealing furnaces and similar purposes where it is necessary to move it about from one furnace to another. The air-pipe, water supply, and waste-water pipes are all connected to the fire tube by flexible tubing as shown in Fig. 25, so as to allow of its free use over a considerable ground space.

*The Steinbart Recording Gauge.*—An accurate, legible, and continuous record of the temperatures measured is second in importance only to their correct indication and convenient observation, in the practical value of a pyrometer, and this end is most satisfactorily accomplished by the Steinbart recording gauge, which forms part of this pneumatic pyrometer.

The gauge is shown in Fig. 27. It consists of a vertical glass cylinder containing mercury in which floats a glass bell, having attached to it a rod with a properly adjusted balance weight. To this hanging rod is attached a small horse-shoe magnet carrying a pen supplied with ink. A small bar of soft iron is placed in such a position that the attraction between it and the magnet brings the pen to bear against a continuous strip of paper moved slowly past it by clockwork. This paper is already printed with vertical time division lines, and before it reaches the pen it is rolled between two rollers, one a plain one, and the other having on it a series of flanges carefully spaced which print the horizontal temperature division lines on the paper as it passes, ink being applied by a pad revolving against it. The paper, after passing the pen, winds automatically on to a spring receiving roller which can be released and the record examined at any time without interfering with the operation of the gauge. An eight-day clock in a dust-proof case at the bottom gives motion to the paper, and the roll of paper is sufficient for 120 days.

Atmospheric pressure is admitted inside the glass float and

the upper part of the inside of the glass cylinder referred to is in connection with the air-pipe from the fire tube to the regulator, so that the same amount of tension or suction is applied in this glass cylinder as in the air-pipe. This suction lifts the

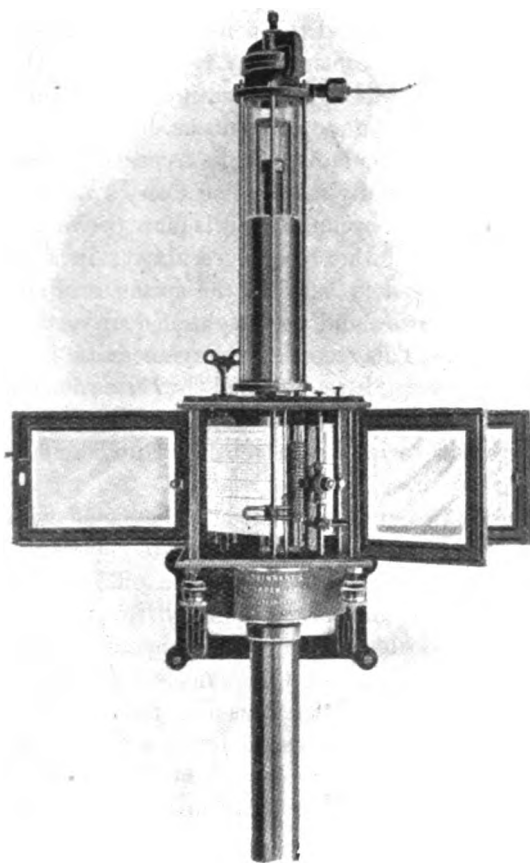


FIG. 27.

glass float more and more out of the mercury in which it floats as the suction increases and allows it to fall as it decreases, and the hanging rod with its attached magnet and pen rises or falls with it, and thus a line is traced upon the paper, which being

moved forward at the same time by the clockwork takes various forms in response to the variations in the suction, and which is a true index of the variations of the temperatures being measured. The pen is set to the temperature line corresponding to the temperature being registered by the regulator, and once correctly set they will continue to rise and fall together. The paper is moved forward until the pen is on the paper time line, and the gauge will then continuously record in ink the temperatures being measured. Thus a continuous, legible record is produced in ink at the same moment as it is indicated by the water column on the regulator. This record can be cut off at any time desired. Usually it is cut off every twenty-four hours, but longer periods may be adopted if it is more convenient to do so. The last seven hours of the record are always in view, and the whole of it can be slacked back on the spring receiving roller at any time for observation and then tightened up again, the gauge recording as usual. This recorder is very accurate and extremely sensitive, and is very little affected by vibrations which are bound to exist in the vicinity of moving machinery. It visibly and legibly records variations in tension equivalent to  $\frac{1}{16}$  of an inch of water column.

Fig. 26 shows two of these recorders connected with a double pyrometer in the relation usually employed.

The pneumatic pyrometer is reliable up to 2500° F., and temperatures of 3000° F. can be measured by it. By its intelligent use, the attendant is able to keep the temperature within a few degrees of the heat ordered by the manager, and the latter can always know whether his instructions have been carried out or not. One of the most valuable features of the autographic attachment is that it gives an unbiassed record of the heat conditions which prevailed at any moment not only for immediate use but for future reference as well.

#### THE WANNER OPTICAL PYROMETER.\*

Made by Dr. R. HASE, Hanover.

The Wanner Optical Pyrometer serves for the measurement of all temperatures above 900° C. It is the first instrument yet

\* This description has been kindly prepared by Dr. A. Weiskopf (Hanover).

invented for the measurement of high temperatures which depends for its application upon an established scientific law, whereas all others hitherto employed are based upon empirical methods. The law determining the relationship of the rays of light to the heat emitted by an incandescent body, is the law enunciated by Wien and Planck, which is discussed further on. Thus, from the quantity of light radiated from a hot body, it is possible to gauge the temperature, and the apparatus for determining this is in reality a photometer. The light under observation enters through a slit, and after traversing lenses and a prism, forms a spectrum from which, by means of a diaphragm, rays of light of an absolute determined wavelength are excluded. The intensity is measured by polarisation. A small electric, incandescent, 6-volt lamp is attached to that end of the apparatus which is directed towards the light under observation, and the light from this is also admitted to the apparatus, and utilised for the purpose of comparison with the intensity to be measured. On looking through the apparatus, the circular field of vision is seen to be divided into two halves, one of which is illuminated by the little electric light, and the other by the light of the body under observation, the coloration being red. By inserting a rotating eye-piece containing a nicol prism, the intensity of the two halves of the field of vision is easily equalised. The angle of rotation is measured on a circular scale, and by reading the angle, the temperature corresponding to it is found in the table which accompanies every instrument. The method simply consists in comparing the rays of a known temperature emitted by the electric lamp, with the rays of an unknown temperature, and the operation is of such extreme simplicity, that every foreman or intelligent workman can become skilled in its use in a very short space of time. The whole apparatus is about 12 inches long, and is made in the form of a telescope. Consequently it can be manipulated with ease, and the distance from the object to be measured is of little importance, as long as the field of vision is fairly filled by the light. It is of course essential that the little electric light should always have the same temperature, otherwise, owing to the variation in the electro-motive force of the accumulator, and the gradual diminution of the power of the light in the course of

time, considerable discrepancies would arise. To obviate any errors of this kind, every apparatus is provided with the means for comparing its standard of lighting power.

Of all methods of determining the temperature of incandescent masses, the oldest is that of estimating it from the colour of the glow. Technical men are best able to judge how easy it is to be led astray by this method, and the years of practice that are necessary in order to become expert. Nevertheless the relationship between the temperature and the kind of rays emitted is governed by a scientific law. As every one knows, white light, after traversing a prism, is decomposed into its several colours, which, apart from the effect upon the human eye, are distinguishable by the number of vibrations of the ether, or by their wave-length. Equally well known is the fact that the several colours, when recombined, become a single white ray again. Supposing then, that, starting at the red end of the spectrum, and closing it together gradually, as it were, the eye took in all the colours, the effect would be much the same as that produced by a glowing body with a continuously rising temperature. Such a body does at first actually appear deep red, then bright red. Yellow then appears, and other colours, until, finally, all colours of the spectrum are radiated in a dazzling white glow. It has long been known that with a rising temperature the strength of the rays of light increases in the order of their change in the spectrum from red to blue. But the law according to which the strength of the rays varies as the temperature rises, and the equation representing the law, were first established experimentally by Professors Paschen, H. Wanner, Lummer and Pringsheim, and were subsequently theoretically deduced by Wien and Planck. Lummer and Pringsheim, of the Physico-technical Institution at Charlottenburg, have proved the validity of this law up to a temperature of  $2500^{\circ}$  C. The result of the investigations is briefly as follows:—

On observing the intensity of a certain colour, apart from considering the changes of colour of a glowing body at rising temperatures, that is to say, a small section of the spectrum, it is found that with increasing temperature the strength of the selected rays increases very considerably. For example, if one

shuts out of the spectrum all the light from a glowing body, from a furnace, for instance, with the exception of the narrow portion which corresponds to the Fraunhofer line C, and if one assumes the intensity of this red light, when at a temperature of  $1000^{\circ}\text{C.}$ , to be equal to 1, by the time the temperature reaches  $1200^{\circ}\text{C.}$  the intensity is 10 times greater; at  $1800^{\circ}\text{C.}$  804 times greater, and at  $2000^{\circ}\text{C.}$  2134 times greater.

This enormous increase in the intensity of the light renders it possible to measure minute differences in the temperature, since even a difference of a tenth of a degree produces a measurable variation in the radiation. If  $I$  represents the intensity of the rays observed,  $T$  the absolute temperature,  $\lambda$  the wave-length of the portion of the spectrum used,  $c_1$  and  $c_2$  two constants, and  $e$  the base of the natural logarithm, the following is the equation which connects the values—

$$\text{I.} \quad I = \frac{c_1}{\lambda^5} \cdot e^{-\frac{c_2}{\lambda T}}.$$

This is Wien's formula, but it is subject to a certain limitation which will be referred to later on. It is of course impossible to express the intensity of light scientifically in any given measure, for the reason that no such measure exists. Consequently it is only possible to compare two intensities with one another. If the standard of comparison be called  $I_0$  and the corresponding absolute temperature  $T_0$ , then—

$$I_0 = \frac{c_1}{\lambda^5} \cdot e^{-\frac{c_2}{\lambda T_0}} \text{ or}$$

$$\text{II.} \quad \frac{I}{I_0} = e^{-\frac{c_2}{\lambda} \left( \frac{1}{T} - \frac{1}{T_0} \right)}.$$

If  $I_0$  and  $T_0$  are known in this equation, that is, the standards for measurement, and also  $I$  and  $c_2$ , then  $T$  alone remains unknown and can be calculated.

The limitation which was alluded to above is the following: In reality the law enunciated applies only to so-called absolutely dark bodies. The nearest approximation to a theoretically dark body is soot. An absolutely dark body absorbs all light which falls on it, consequently it also radiates light of every colour and



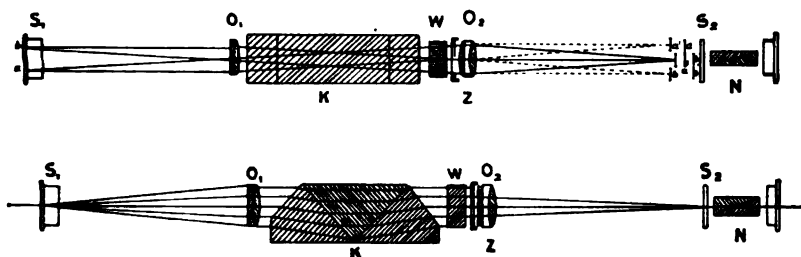
wave-length. Bright platinum reflects much light and absorbs little, and therefore is the antithesis of the dark body. Iron in the incandescent state scarcely reflects at all, consequently it closely approximates to the properties of the dark body. According to Kirchhoff, a theoretically dark body is a hollow space entirely surrounded by walls which are impervious to heat and perfect reflectors. The same effect would be attained, if instead of the walls being reflecting they were of the same constant temperature as the hollow space, so that whatever heat was radiated from the space to the walls would be radiated back from the walls to the space. By making a small aperture in the wall the radiation is not altered in a measurable degree: it remains in fact absolutely dark. It will be readily understood from this that in all closed furnaces the necessary conditions are fulfilled, for in the first place the walls are made as impervious to heat as possible, from which the second condition naturally follows that the wall has the same temperature as the interior. In almost every case of a glowing solid or liquid body, the correctness of this law may be taken for granted, since even when the body is at first not theoretically dark, it approximates more and more to the dark state as it grows hotter, so that the difference is practically negligible.

The principle is thus theoretically established, by which the temperature of solid and liquid glowing bodies may be gauged from the intensity of the light-rays of a small spectral field.

The determination of the temperature of colourless flames cannot be effected by the optical pyrometer, for the reason that the radiation of the flame differs so greatly from the radiation of a dark body that the law of Wien is no longer applicable. Nevertheless it is possible to ascertain the temperature of the Bessemer converter from the light radiated by the escaping gases. Since it is only the temperature of dark bodies that can be correctly measured, the precaution is always adopted in testing the apparatus of comparing it with the Le Chatelier pyrometer in order to ensure that it registers correctly. The difficulty in checking the measurements in this manner lies in the fact that the Le Chatelier thermoelement is only in contact with one particular spot in the space or object, which possibly may not fall within the range of the optical pyrometer.

The construction of the optical portion may be gathered from the accompanying figures (28 and 29), which represent two longitudinal sections of the photometer along planes at right angles to each other.

At  $S_1$  are two slits  $a$  and  $b$  placed vertically one above the other;  $O_1$  is a lens, fixed at a point equal to its focal distance from  $S_1$  which makes the rays parallel.  $K$  is a direct vision prism. Every beam passing through  $a$  and  $b$  is dispersed by the spar polariser  $W$  into two polarised parts perpendicular to one another.  $Z$  is a double prism by which the rays on either side are deviated towards the axis. The rays are collected by the lens  $O_2$  which forms images of  $a$  and  $b$ , directly in front of the slit  $S_2$  (the ocular slit), two images of each appearing owing to the ordinary and extraordinary rays. The dimensions of the prism  $Z$  are so



FIGS. 28 and 29.

contrived that an image of  $a$  (the ordinary rays) and one of  $b$  (the extraordinary rays) coincide exactly before the slit. It is evident that to form the image of  $a$  in front of the slit  $S_2$  only the upper half of the prism  $Z$  can come into play, while the image of  $b$  can in like manner only be produced by the lower half. Both images are, however, polarised vertically to each other, and the eye behind  $S_2$  therefore views the upper half of  $Z$  illuminated by  $a$ , and the lower half illuminated by  $b$ . By means of the revolving nicol prism  $N$ , or the analyser, either one or other of the images can be intensified or weakened.

The spectroscope is thus composed of the parts of  $S_1$ ,  $O_1$ ,  $O_2$ , and  $K$ , while the photometer consists of the parts  $W$ ,  $Z$  and  $N$ . By opening the slit  $S_2$  wide, and observing the red hydrogen line for instance, the image seen is similar to that shown in Fig.

30. For the sake of clearness,  $a$  and  $b$  in the centre are shown crosswise, though in reality they both coincide. The arrows indicate the direction of the vibrations of the images. The upper image of  $a$  and the lower one of  $b$  are shut off by the slit  $S_2$ . The light is thus decomposed by a direct vision prism, and then shut off with exception of the small portion which corresponds to the Fraunhofer line C, so that on looking at objects through the instrument they appear to give a red light.

The intensity of the rays of light is determined by means of

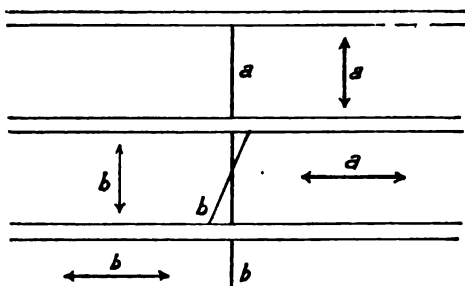


FIG 30.

polarising prisms, of which one is fixed within the revolving eye-piece. The amount of the rotation is read off on a circular scale, and this serves as a measure of the intensity.

### THE WIBORGH THERMOPHONE.

Made by Messrs. HENRY SIMON, LIMITED, Manchester.

These thermophones provide a cheap and trustworthy means for measuring high temperatures in place of pyrometers. They consist of small calcined cylinders which are placed in the furnace or chamber of which the temperature is to be ascertained, and explode with a sharp crack at the end of an interval of time corresponding to the actual temperature of the furnace.

Temperatures of from 600° Fahrenheit to 4000° Fahrenheit can be determined with accuracy by means of these thermophones, which can be used for blast and all other furnaces, chimneys, baths of molten metal, in fact in all places where

intense heat has to be measured. They must be deposited in the region where the temperature is to be ascertained, and by means of a timekeeper the number of seconds which elapse from the time the thermophone is placed in position until it explodes is carefully noted. The corresponding temperature is then found by referring to a table supplied with the cylinders.

### THE ZAUBITZ PYROMETER.

Made by A. ZAUBITZ, New York.

This instrument is designed to serve as a stationary pyrometer for registering the temperature of the hot-blast in smelting iron and of the gases in boiler flues and chimneys. It is also adapted for indicating the temperature in annealing and case-hardening ovens, kilns, and glass-bending ovens. When adapted for hot-blast the working range is  $1200^{\circ}$  to  $1400^{\circ}$  Fahrenheit. The Standard Portable Pyrometer has also been designed by the same maker as a test gauge for fixed instruments which are constantly exposed to hot air or gases. It is quick in action, sensitive and accurate, and provided with non-corrosive movement and an expansion stem. All the working parts are made of phosphor bronze. Another type has been specially constructed for controlling the temperature of tinning and galvanising baths; one of the improvements consisting in the method adapted to protect the stem from the destructive effect of the molten zinc. The protector consists of a piece of pipe with one end closed, the interior of which is filled with lead, which metal has no corrosive effect on the stem, and secures the same result as though the pyrometer were immersed in the zinc. For annealing furnaces, platinum is used in the construction of the instrument, and it is calibrated to register up to  $3000^{\circ}$  Fahrenheit.

### A LIST OF BRITISH PATENTS FOR PYROMETERS.

By H. G. GRAVES, Assoc. R.S.M.

The discovery of a means for measuring temperature can be carried back nearly a decade more than three centuries, as it is generally supposed that Galileo invented the thermoscope about

1597, though the discovery has also been ascribed to Cornelius Drebbel and others. Possibly the idea was even older. The need for regulating temperature was appreciated by Ben Jonson, who wrote—

“Look well to the register  
And let your heat still lessen by degrees  
To the aludel.”

(*The Alchemist*, Act ii. Scene 1.)

The term “thermometer” did not come into use for some little time, one of its earliest occurrences being in H. van Etten’s *Recreation Mathématique*, 1626. The word “pyrometer” is of even later origin, but it was in use by Peter van Musschenbroek in 1731, and, following him, by Desaguliers\* in 1734, to describe instruments they used for measuring the expansion of metal by heat. In 1754 Smeaton† used the word in a similar fashion. There is not a very marked line of demarcation between thermometry and pyrometry, and naturally endeavours were made at a very early date to measure high, as well as ordinary, temperatures. Perhaps one of the most interesting is divulged in a paper contributed anonymously to the Royal Society by Newton‡ in 1701. This paper, written in Latin, describes a scale of temperatures and a method of determination based on the rate of cooling of a red-hot bar of iron freely exposed to the air. This method was followed up to some extent by others. About 1782 Wedgwood proposed his famous test, which depends on the shrinkage of clay as it is burnt. He was fully aware of the difficulties attendant on the method, but in 1786 was able to show§ how results, more or less uniform, might be obtained. For the early history of pyrometry, reference may be made to a classified bibliography of physical sciences given by Thomas Young as an appendix to his *Course of Lectures on Natural Philosophy and Mechanical Arts*, which was published in two volumes in 1807.

As Barus || has so truly observed, there are few phenomena in

\* “A Course of Experimental Philosophy,” vol. i. p. 421.

† *Philosophical Transactions*, vol. xlviii. p. 598.

‡ *Ibid.*, vol. xxii. pp. 824–829.

§ *Ibid.*, vol. lxxvi. p. 390.

|| *Proceedings of the American Association for the Advancement of Science*, vol. xlv. p. 65.

physics which have not in some way or other been impressed into pyrometric service, often indeed by methods of exquisite physical torture. Comparatively few of these phenomena, however, have been made the basis of patents, nearly all of which fall fairly well into the practical classification adopted by Le Chateleur\* and Boudouard; and their lines are mainly followed in the classified lists of patents given below. A more extensive classification has also been given by Barus,† with an admirable summary of the historical and scientific sides of the question.

Before 1850, the patents taken out for devices for measuring temperature are few and far between. The earliest British patent appears to be No. 3206 of 1809, granted to Stephen Hooper of Walworth for "A thermometer or machine for ascertaining the heat of baker's ovens, and various other purposes." This appliance might be described as a pyrometer though it only depended on the relative expansion of a brass tube and a wooden rod, yet it was the precursor of numerous devices of similar character and purpose. The next recorded patent is for James Kewley's balanced mercurial thermometer in 1816. After 1850 patents became more numerous, and, at the present time, the yearly average is over a dozen thermometers and pyrometers. An account of them will be found in those volumes of classified abridgments of specifications, entitled "Philosophical Instruments," which are published periodically at the Patent Office. In the indexes of these volumes, no division is made between instruments for measuring high and low temperatures respectively, but in the following lists an attempt has been made to differentiate them. Such appliances as clinical thermometers, which are very numerous, and alcohol or mercurial thermometers generally, have been excluded, but attempts to make a mercurial thermometer suitable for high temperatures by increasing the pressure and so raising the boiling point, have been included (*e.g.* Murrie's Patents, Class A). On the other hand it has not been thought worth while to give a list of the numerous bimetallic thermometers of the Breguet type which have a compound metal strip, though it must be confessed that they often approximate closely

\* *Mesure de températures élevées*, Paris, 1900; also translation by G. K. Burgess, New York, 1901.

† *United States Geological Survey Bulletin*, No. 54.

to the simple form of the metal bar expansion type. Recording instruments of the thermograph type, mainly used with mercurial or aneroid thermometers, are also excluded.

Only British patents have been dealt with, but it may be noted here that United States patents for pyrometers and for heat recorders are collected in the classes 73, sub-class 32, and class 234, sub-class 11 of the United States classification. Similarly the German Office includes thermometers, pyrometers, &c., in their class 42i and the French in class 12, sub-class 2. These may be seen at the library of the Patent Office, 25 Southampton Buildings, London, W.C.

The inventions, indexed in the lists below, cover not only the absolute construction of the pyrometer itself but also embrace the indicating and recording appliances stated to be applicable for use in conjunction with them, and such appliances are included under the type to which they are applied.

The names given in *italics* are those of foreign inventors who have applied for a patent through an intermediary.

#### CLASSIFIED LISTS OF BRITISH PATENTS FOR PYROMETERS.

##### A.—*Expansion of Air or Vapour, or of Liquid under Pressure, mainly Air and Mercury Vapour Thermometers.*

Year.	Number.	Name.
1866	1,470	Weatherdon, B. F. ( <i>Durand, J. J. M., and Pichoin, C.</i> ).
1871	965	Siemssen, G.
1876	3,525	Maw, W. H., and Dredge, J. (provisional specification only).
1877	1,716	MacDonald, A. S. L.
1878	3,522	Ducomet, J.
1879	3,060	Budenberg, A. ( <i>Seyferth, A., and Budenberg, C. F.</i> ).
1879	3,712	Bowkett, W. D.
1882	4,302	Plunkett, J. W.
1884	3,750	Beilby, G. T.
1884	6,093	"
1884	9,363	Murrie, J.
1884	10,231	Cox, J. B.
1884	15,947	Murrie, J.
1884	16,621	"
1885	303	"
1885	10,805	"
1886	3,023	"
1888	2,673	Wiborg, J. G.
1888	7,884	Trotter, A. P.
1889	20,139	Siegert, A., and Dürr, W.
1890	10,380	Murrie, J.
1891	10,456	Callendar, H. L.
1892	9,026	Richard, J.

Year.	Number.	Name.
1893	23,947	Crooke, W.
1894	7,444	Thompson, W. P. ( <i>Karlander, K. V., and Meyerson, O.</i> ).
1895	10,886	Heys, W. E. ( <i>Schäffer &amp; Budenburg</i> ).
1900	17,912	Mills, B. J. B. ( <i>Bristol Co.</i> ).
1901	2,467	Hatfield, H. S.
1901	6,313	"
1901	11,052	Arndt, M.

*B.—Expansion of Solids, excluding Compound Metal Strips as used in the Breguet Type of Thermometer.*

Year.	Number.	Name.
1809	3,206	Hooper, S.
1855	684	Hudde, F. E., and Fouquet, J. B. E.
1858	2,744	Adcock, H.
1859	104	May, C. N.
1860	1,784	Robertson, A., and Ritchie, A.
1861	2,664	Chesterman, J.
1862	1,528	Petrie, W.
1863	1,449	Clark, W. ( <i>Merlançon, A.</i> ).
1866	3,101	Wood, C. (provisional specification only).
1868	61	Norton, J. L., and Bailey, W. H.
1868	3,771	Bailey, W. H.
1871	907	Newton, W. E. ( <i>Spencer, R.</i> ).
1872	949	Bailey, W. H.
1872	984	Casartelli, J. L.
1873	1,271	Hobson H.
1873	2,671	Smith, J. T. ( <i>Tremeschini &amp; Cie</i> ).
1875	1,012	Dixwell, G. B.
1875	1,832	Wood, R. J.
1875	4,225	Huet, A. F. (provisional specification only).
1876	3,706	Johnson, J. H. ( <i>Dion, C., and Baylis, J.</i> ).
1878	2,438	Steinle, O.
1879	5,274	King, H. J. H.
1881	1,357	Bailey, W. H. ( <i>Zipf &amp; Lungsdorf und Berlin Anhaltische Maschinenbau Aktiengesellschaft</i> ).
1881	1,417	Pase, M. D. (provisional specification only).
1882	5,894	Winch, G. L.
1884	11,179	Stromeyer, E. C.
1885	7,147	Müller, W. ( <i>Derckmann, C.</i> ).
1887	2,345	McCarthy, D.
1887	4,135	Haight, H. J.
1888	2,309	Richard, J., and Richard, T.
1888	7,884	Trotter, A. P.
1888	16,457	Brodie, G. C., and Prior, J. D.
1890	6,661	Brophy, M. M.
1890	11,705	Walker, S. S.
1891	12,058	Damaze, L.
1892	11,177	Murdock, H.
1893	6,655	Boult, A. J. ( <i>Brown, E.</i> ).
1894	13,929	Woodward, H. H.
1894	15,226	Brodie, G. G., and Prior, J. D.
1895	5,531	Leslie, A. C. S. B. ( <i>Klapp, F. D.</i> ).
1895	12,296	Lake, W. R. ( <i>Sellers, W.</i> ).
1896	4,843	Harland, A. P., Wright, F. M., and Ursina, D. A.
1900	7,905	Patent Agglomment Fuel Syndicate, Forrester, H. C. B., and Yeo, J. A. A.
1901	21,335	Batault, E.
1902	4,963	Watkinson, W. H.
1902	5,312	Chauvin, R., and Arnoux, R.
1903	14,418	Stevenson, J. L.



C.—*Calorimetric Method.*

Only one patent appears. It describes the use of a ball of platinum and the arrangement of the water-bath.

Year.	Number.	Name.
1862	1951	Byström, O. F.

D.—*Electric Resistance and Thermo-electric Pyrometers.*

Year.	Number.	Name.
1883	4,163	Enright, J. (provisional specification only).
1885	4,815	Lorrain, J. G.
1887	14,509	Callendar, H. L.
1888	13,005	Grindley, W. H., and Hensley, W. S.
1890	11,042	Gooch, J. W., Baker, C. A., and White, W.
1891	5,342	Callendar, H. L.
1891	22,326	"
1895	7,293	Simonds, A. A.
1895	10,685	Whipple, G. C., and Warren, H. E.
1896	2,051	Burstall, H. R. J., and Burstall, H. F. W.
1897	16,718	Callendar, H. L.
1899	16,926	Darwin, H., Griffiths, E. H., and Wetham, W. C. D.
1902	918	Whipple, R. S.
1902	11,765	Crawley, C. W. S., and Trotter, A. P.
1902	12,796	Johnson, J. Y. ( <i>Boehringer &amp; Söhne, C. F.</i> )
1902	21,118	Patterson, A.

E.—*Heat Radiation.*

Year.	Number.	Name.
1867	810	Bischof, G.
1873	3,647	Hicks, J. J.
1875	3,860	Crookes, W.
1877	2,708	Gardner, H. ( <i>Trcmeschini, J. A., and Lion, F.</i> )
1883	4,443	Siemens, W. (provisional specification only).
1893	18,652	Lataste, C.

F.—*Light Radiation.*

Year.	Number.	Name.
1890	12,372	Uhler, L. C., and Depresle, H. E. A.
1900	19,400	James, R. W. ( <i>Bethlehem Steel Co.</i> ).
1900	19,401	" "
1900	19,402	" "
1900	19,604	Wise, W. L. ( <i>Morse, E. F., Coz, J. D., and Prentiss, F. F.</i> )

G.—*Fusibility; Metals, Seger Cones, &c.*

Year.	Number.	Name.
1878	1,136	Wise, W. L. ( <i>Grouven, H.</i> ).
1878	3,522	Ducomet, J.
1880	5,504	Wise, W. L. ( <i>Grouven, H.</i> ).
1893	14,804	Gartrell, J. H.
1895	3,379	Watson, G., James, C. W., and Bullock, R. L.
1898	8,426	Holdcroft, J. P., Jackson, W., and Tomkinson, A.
1900	6,288	Watkin, H.

H.—*Air and Water Circulation ; a flow of fluid is maintained through, or air is withdrawn from, the heated space, and its proportional temperature observed directly or indirectly.*

Year.	Number.	Name.
1863	1,084	Holcroft, G. (provisional specification only).
1866	3,101	Wood, C. (provisional specification only).
1868	3,771	Bailey, W. H.
1872	984	Casartelli, J. L.
1873	1,371	Hobson, H.
1875	127	Main, R.
1877	2,708	Gardner, H. ( <i>Tromeschini, J. A., and Lion, F.</i> ).
1878	2,400	Saintignon, F. A. J. B., Comte de
1882	2,163	Sauvée, A. ( <i>Amagat, E. H.</i> ).
1883	1,698	Wise, W. L. ( <i>Boulrier, A., and Boulrier, E.</i> ).
1883	1,739	Longden, A. ( <i>Krupp, A.</i> ).
1883	4,751	Wise, W. L. ( <i>Boulrier, A., and Boulrier, E.</i> ).
1885	2,568	Frew, J.
1893	15,484	Uehling, E. A., and Steinbart, A.
1894	9,664	„ „

#### I.—*Miscellaneous.*

Year.	Number.	Name.
1879	4,754*	Brunton, J. D. ( <i>Gossiaux, L.</i> ).
1880	3,213†	Bamber, E. F.
1892	15,489‡	Negretti, H. P. J., and Zambra, M. W.
1895	6,284§	Wiborg, J. G.

\* Pyrometer attachment to miner's safety-lamp.

† Fusible metal replaces mercury in thermometer.

‡ Thermometer enclosed in bad conductor of heat.

§ Explosive or coloured fire enclosed in bad conductor of heat.

## BIBLIOGRAPHY.

The following is a list of the more recent memoirs dealing with pyrometry :—

1871. SIEMENS, Sir C. W. *Journal of the Iron and Steel Institute*, 1871, p. 50.  
[Describes the Siemens electric pyrometer.]
1883. *Iron and Coal Trades Review*, vol. xxviii. p. 693.  
[An exhaustive article reprinted from the *Portefeuille Economique des Machines* describing the pyrometers of Tremeschini, Tramplér, Ducomet, Saintignon, Amagat, and Boulrier.]
1884. CARNELLEY, T., and T. BURTON. *Journal of the Chemical Society*, 1884, pp. 237–241.  
[Describes the Carnelley and Burton pyrometer.]
1884. GAUNTLETT, W. H. *Iron and Coal Trades Review*, vol. xxviii. p. 694.  
[Describes the Gauntlett pyrometer.]
1886. BERGEN, A. VON. *Journal of the Iron and Steel Institute*, 1886, p. 207.  
[Describes Krupp's hot-blast pyrometer.]
1886. HEISCH and FOLKARD. *Iron Age*, vol. xxxvii. No. 25.  
[Describes the Heisch and Folkard pyrometer.]
1888. WIBORGH, J. *Journal of the Iron and Steel Institute*, 1888, No. II. p. 110.  
[Describes a new air pyrometer.]
1888. EVRARD, A. *Génie Civil*, vol. xiii. p. 43.  
[Describes the Mesuré and Nouel pyrometer.]
1889. BARUS, C. *United States Geological Survey Bulletin*, No. 54.  
[Gives a historical account of pyrometry.]
1889. KNAB, L. *Le Génie Civil*, vol. xvi. pp. 327–331.  
[Describes the pyrometer of F. de Saintignon.]
1890. HOWE, H. M. *Engineering and Mining Journal*, vol. xlix. pp. 637–638.  
[Describes the means for measuring high temperatures.]
1890. ERNST, C. VON. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. p. 533.  
[Discusses the Mesuré and Nouel pyrometer.]
1890. HOWE, H. M. *Engineering and Mining Journal*, vol. l. pp. 427–428.  
[Describes Le Chatelier's pyrometer.]
1891. PHILLIPS, J. A., and H. BAUERMAN. *Elements of Metallurgy*, p. 27.  
[Describes the Mesuré and Nouel pyrometer.]

1891. ROBERTS-AUSTEN, Sir W. C. *Journal of the Iron and Steel Institute*, 1891, No. I. p. 90.  
[Describes automatic methods of observation with the Le Chatelier pyrometer.]
1891. LE CHATELIER, H. *Comptes Rendus de l'Académie des Sciences*, vol. cxiv. pp 214-216.  
[Describes an optical method for the determination of high temperatures.]
1891. CRUM, J. *Journal of the Iron and Steel Institute*, 1891, No. II. p. 130.  
[Describes the Wiborgh air pyrometer.]
1892. THWAITE, B. H. *Journal of the Iron and Steel Institute*, 1892, No. I. p. 183.  
[Describes optical pyrometers.]
1892. TROTZ, E. *Transactions of the American Institute of Mining Engineers*, vol. xxi. p. 592.  
[Describes the Wiborgh air pyrometer.]
1892. CALLENDAR, H. L. *Journal of the Iron and Steel Institute*, 1892, No. I. p. 164.  
[Describes platinum pyrometers.]
1892. ROBERTS-AUSTEN, Sir W. C. *Journal of the Iron and Steel Institute*, 1892, No. II. p. 33.  
[Describes an appliance for autographically recording the temperature of furnaces.]
1892. SEGER. *Berg- und Hüttenmännische Zeitung*, vol. li. pp. 90-91.  
[A lecture on pyrometry delivered before the Society of German manufacturers of Refractory Products.]
1892. BRAUN and HARTMANN. *Stahl und Eisen*, vol. xii. pp. 656-657.  
[Describes the Braun and Hartmann pyrometer which, in principle, is a modification of the Siemens pyrometer.]
1892. HOLBOEN, L., and W. WEIN. *Zeitschrift für Instrumentenkunde*, vol. xii. pp. 257, 296.  
[Describes their series of tests with the Le Chatelier pyrometer and air pyrometer.]
1892. ROBERTS-AUSTEN, Sir W. C. *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cx. pp. 152-186.  
[Describes several instruments for measuring high temperatures.]
1892. BLASS, E. *Stahl und Eisen*, vol. xii. pp. 893-909.  
[Discusses the accuracy of various pyrometers.]
1893. ROBERTS-AUSTEN, Sir W. C. *Journal of the Iron and Steel Institute*, 1893, No. I. p. 112.  
[Describes the recording pyrometer.]

1893. ROBERTS-AUSTEN, Sir W. C. *Transactions of the American Institute of Mining Engineers*, vol. xxiii. p. 407.

[Deals generally with the history of heat treatment, and describes the forms of apparatus used for the determination of high temperatures.]

1893. FARKELL, G. C., and H. G. HAMMAN. *The Sibley Journal of Engineering*, vol. vii. pp. 53-57.

[Discusses the determination of temperature by the change in the electrical resistance of conductors.]

1893. SIEGERT, A., and W. DÜRR. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 291.

[Describes the Siegert-Dürr air pyrometer.]

1893. GRATIGNY, R. K. *Engineering and Mining Journal*, vol. lvi. pp. 321-322.

[Describes some of his experiences with the Le Chatelier thermocouple.]

1894. HOWE, H. M. *Transactions of the American Institute of Mining Engineers*, vol. xxiv. p. 746.

[Deals with the Le Chatelier pyrometer.]

1894. GAAB, C. Abstract of a paper communicated to the Iron and Steel Institute, May 1894.

[Describes the air-pyrometer, patented by W. Dürr and A. Siegert.]

1894. BARUS, C. *Bulletin of the United States Geological Survey*, No. 103.

[Deals with the thermo-electric measurement of high temperatures.]

1894. JÜPTNER, H. VON. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlii. pp. 409-410.

[Describes the air pyrometer devised by Otto Meyerson and K. V. Karlander.]

1894. MORTON, H. *Engineering*, vol. lviii. pp. 251-252.

[Describes the apparatus designed by E. A. Uehling and A. Steinbart for the measurement of high or low temperatures.]

1894. WRIGHT, C. ALDER. *Industries and Iron*, vol. xvii. pp. 128, 149, 176, 194.

[Deals generally with the subject of pyrometry.]

1894. PINZGER, H. *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxviii. pp. 1547-1548.

[Describes the Wiborgh air pyrometer.]

1895. MORTON, H. *Engineering*, vol. lix. pp. 208-209.

[Describes the results obtained with the pneumatic pyrometer in practical use.]

1895. HEYCOCK, C. T., and T. H. NEVILLE. *Journal of the Chemical Society*, vol. xlvii. pp. 160-199.

[Describes the method and instruments used for the determination of high temperatures by means of platinum-resistance pyrometers.]

1895. THOMPSON, F. E. *Iron Age*, vol. lv. pp. 374-377.  
[Describes the use of Mesuré and Nouel's optical pyrometer.]
1895. WIBORGH, J. *Teknisk Tidskrift*, vol. xxiv. pp. 69-70.  
[Describes the Karlander-Meyerson air pyrometer.]
1895. BERTHELOT, D. *Comptes Rendus de l'Académie des Sciences*, vol. cxx. p. 831.  
[Describes a method of measuring temperatures.]
1896. BRAUBACH, G. *Stahl und Eisen*, vol. xvi. pp. 207-209.  
[Describes a modified form of pyrometer, dependent on the method of mixtures.]
1896. WAGGENER, W. J. *Annalen der Physik*, vol. lviii. p. 579.  
[Detailed study of the Bunsen flame with the aid of the Le Chatelier pyrometer.]
1896. BRAUBACH, G. *Stahl und Eisen*, vol. xvi. pp. 572-573.  
[Describes a pyrometer for the determination of the temperature of the blast in blast-furnaces.]
1896. WEDDING, H. *Stahl und Eisen*, vol. xvi. pp. 660-665.  
[Describes the Le Chatelier-Heræus pyrometer, and gives brief descriptions of the Siemens electric pyrometer, the Gauntlett expansion pyrometer, and the Seger cones.]
1896. WIBORGH, J. *Jernkontorets Annaler*, vol. li. pp. 102-128.  
[Describes the pyrometers of Steine and Hartung, Gauntlett, Hobson, Siemens, Le Chatelier, and the Mesuré-Nouel.]
1897. HOLBORN, L. *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. pp. 226-227.  
[Describes the use of the Le Chatelier pyrometer.]
1897. JÜPTNER, H. VON. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 99-104.  
[Describes the Wiborgh thermophone, and gives tables connected with its use in practice.]
1897. ROBERTS-AUSTEN, Sir W. C. *Proceedings of the Institution of Mechanical Engineers*, 1897.  
[The Fourth Report of the Alloys Research Committee refers to certain experiments, the results of which have improved the recording pyrometer, and have rendered its calibration more accurate.]
1897. ROBERTS-AUSTEN, Sir W. C. *Journal of the Society of Chemical Industry*, vol. xvi. pp. 5-9.  
[Discusses the industrial uses of the recording pyrometer.]
1897. ERNST, C. VON. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 300-302.  
[Describes the principle on which the Le Chatelier pyrometer is based, and describes its construction.]

1897. BICHAT. *Revue Industrielle de l'Est*, 1897.  
[Describes the multiplicity of phenomena used in the construction of pyrometers.]
1898. WIBORGH, J. G. *Baumaterialienkunde*, vol. ii. p. 50.  
[Describes the use of the thermophone.]
1898. CHREE, C. *Nature*, vol. lviii. pp. 304-307.  
[A memoir on recent work in thermometry, containing descriptions of various pyrometers.]
1898. KERSTEN, J. *Revue Universelle des Mines*, vol. xliii. pp. 44-62.  
[Describes the pneumatic pyrometer devised by Uehling and Steinbart.]
1898. STANSFIELD, A. *Philosophical Magazine*, vol. xlv. pp. 59-81.  
[On some improvements in the Roberts-Austen recording pyrometer with notes on thermo-electric pyrometry.]
1899. WALLER, T. H. *Proceedings of the South Staffordshire Institute of Iron and Steel Works Managers*, vol. xiv. pp. 77-88.  
[Deals with the measurement of high temperatures, and describes the various forms of pyrometers.]
1899. UEHLING and STEINBART. *Stahl und Eisen*, vol. xix. pp. 431-438.  
[Describes in detail the Uehling and Steinbart pyrometer.]
1899. BROWN, E. *Iron Age*, April 6, 1899, pp. 10-11.  
[Describes the various pyrometers made by him.]
1899. BARUS, C. *Proceedings of the American Association for the Advancement of Science*, vol. xlv. pp. 65-92.  
[Deals with long-range temperature and pressure variables in physics.]
1899. HILL, A. *Journal of the West of Scotland Iron and Steel Institute*, vol. vii. pp. 61-72.  
[Describes the thermo-electric couple used with a special form of the D'Arsonval galvanometer.]
1900. UEHLING, E. A. *Proceedings of the Cleveland Institution of Engineers*, 1900, pp. 61-94.  
[Describes his pneumatic pyrometer and autographic recorder.]
1900. LE CHATELIER, H., and O. BOUDOUARD. *Mesure des Températures Elevées*, 8vo, pp. 220. Paris.  
[Describes the various forms of pyrometers in succession, according to the physical principles involved in each. A bibliography is appended.]
1900. HOLBORN, L., and A. L. DAY. *American Journal of Science*, vol. x. pp. 171-206.  
[Describes their investigations on a gas thermometer consisting of a platinum-iridium bulb used at high temperatures.]
1900. BRISTOL, W. H. *Transactions of the American Society of Mechanical Engineers*, vol. xxii. p. 143.  
[Describes a recording pyrometer with a porcelain air-bulb connected by a capillary tube to a Bourdon pressure-gauge which has an automatic recording attachment.]

1900. JACOBUS, D. S. *Proceedings of the American Association for the Advancement of Science*, vol. xlix. p. 151.  
[Describes a Le Chatelier pyrometer, in which any error due to variations in the resistance of the platinum and platinum-rhodium element is eliminated.]
1901. CALLENDAR, H. L. *Proceedings of the Royal Institution of Great Britain*, vol. xvi. pp. 97-113.  
[Discusses the measurement of extreme temperatures.]
1901. ROSENHAIN, W. *Electro-Chemist and Metallurgist*, vol. i. pp. 141, 163.  
[Describes the Griffith-Calendar, Le Chatelier, and Roberts-Austen pyrometers.]
1901. BURGERS, G. K. Translation of Le Chatelier and Boudouard's book, 8vo, pp. 230. New York.
1902. WANNER, H. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. l. pp. 99-101.  
[Discusses the methods in use for determining high temperatures, and criticises the Le Chatelier, Hempel, and Holborn and Kurlbaum pyrometers.]
1902. HOLBORN, H., and KURLBAUM, F. *Engineering*, vol. lxxiv. p. 561.  
[Describes their optical pyrometer.]
1902. DREICHLINGER. *Stahl und Eisen*, vol. xxii. pp. 1309-1310.  
[Describes an optical pyrometer.]
1902. WEDDING, H. *Sitzungsbericht des Vereins zur Beförderung des Gewerbelebens*, 1902, pp. 196-207.  
[Describes Siemens and Halske pyrometer, and notes various principles upon which the construction of recording pyrometers are based.]
1902. THIELE, H. *Zeitschrift für angewandte Chemie*, vol. xxxi. pp. 780-782.  
[Describes an apparatus for determining the melting-point of metals.]
1902. SEGER, H. A. *Records of the Royal Porcelain Factory, Berlin*.  
[Describes the refractory nature of clays and the use of his cones for determining temperatures.]
1902. WHIPPLE, R. S. *Proceedings of the Physical Society*, vol. xviii. p. 235.  
[Describes a temperature indicator for use with platinum thermometers.]
1903. NATIONAL BUREAU OF STANDARDS AT WASHINGTON. *Iron Age*, August 6, 1903, p. 5.  
[Prepared to test and calibrate pyrometers with the aid of electric resistance furnaces.]
1903. LUMSDEN, J. S. *Journal of the Chemical Society*, vol. lxxxiii. pp. 349-351.  
[Describes a new form of air pyrometer.]
1904. SCHÜTZ, L. H. *Zeitschrift des Vereins deutscher Ingenieure*, vol. xlvi. p. 155.  
[Describes the recent advances in the measurement of high temperatures.]



*DISCUSSION.*

Mr. J. E. STEAD, Member of Council, said it was very interesting to him, and he thought it would be to all, to find that they had such a very excellent collection of apparatus presented for their inspection at that meeting. At the last meeting of the Institute it was suggested that in May there should be a Pyrometer Exhibition, and he thought the admirable paper prepared by Mr. Brough, and the exhibition, were most valuable. Many years ago, the Siemens pyrometer was the only pyrometer of any real use on the market. Later, Mr. Siemens produced a resistance pyrometer which, in an improved form, was exhibited in the Hall below. He did not intend to further discuss the relative merits of the various pyrometers, but would confine his remarks to one point which should be thoroughly discussed, and that was the question of applying those pyrometers in practical use. The various forms were not all adapted for the same purpose. When one attempted to take the temperature of a large mass, or even of a small mass, of commercial steel in a furnace, it was not so easy to do so as would be expected. He was afraid that many of the recorded results of temperatures of heated steel were not absolutely to be relied upon for that reason. Sometimes the pyrometer was simply put into the furnace itself, and instead of the temperature of the steel, the temperature of the furnace was obtained. The temperature of the furnace and the temperature of the steel may be very different, unless the metal is left in the furnace till it reaches the temperature of the furnace itself. In experiments he had made with the Le Chatelier pyrometer, a "couple" was put into the furnace in which steel bars of about 90 lbs. per yard were being heated. Immediately the "couple" was put in it indicated a furnace temperature above  $1000^{\circ}\text{C}$ .; but on placing it between the two bars, placed side by side, it only showed  $800^{\circ}\text{C}$ .

In his experiments with Mr. A. W. Richards at Middlesbrough, they did the heating by placing two bars close together, and the "couple" was inserted between them. In that way they got a result which approximated closely to the actual temperature of the steel itself. In laboratory experiments, it

had been customary to drill small holes into the bars and insert the "couple" into them. That was a most perfect way; but when one was heating a piece of steel for commercial purposes, drilling into it before starting to heat was inadmissible.

One method which had been suggested was that of placing a saddle, or several saddles, of steel over the pieces to be heated. These might have holes drilled into them large enough to admit of the insertion of the pyrometer couples, &c., and in that way obtain a record which would approximate to the temperature of the mass of the steel itself.

He had no doubt that many steel-makers had found difficulties and had overcome them, and his object in opening the discussion was to lead it in the direction indicated. It seemed important that when one had correct and good pyrometers, they should be able to use them in such a way as to get results which were not misleading.

Professor H. LE CHATELIER (Paris) was gratified to see the interest accorded his researches in pyrometry, and the success which had attended his thermo-electric thermometer. He thought, however, that in view of the inevitable alteration in the platinum couples at high temperatures the future would belong for measuring temperatures above  $1000^{\circ}\text{C.}$  to radiation pyrometers. He had been surprised to see that the employment of his optical pyrometer, and of similar apparatus of more recent date, such as that of Lummer and of Wanner, for example, had not become more widespread in metallurgical works. He thought some slight misapprehension existed in certain quarters as regarded the difficulties involved in photometric measurements. A very ordinary degree of accuracy was required in these measurements, for the radiancy of incandescent bodies varied, according to temperature, with such swift adhesion to the law which determined these variations that errors amounting to 25 per cent. on the observed luminous intensities did not greatly affect the result. In view of this misapprehension he had busied himself for some time in devising a system of pyrometry by radiation, requiring no photometrical measurements, and involving the use of perfectly simple appliances capable of being employed by any workman. Their principle might be explained

as follows: If a body, which he might call A, were placed in the centre of two concentric spherical covers, B and C, at different temperatures, the inner one, B, is at the surrounding temperature, and the outer one, C, at the temperature of the body under examination. If an opening be made in the inner sphere B in such a manner that the heat from the area C can pass directly to A, the temperature which the latter will assume will be the mean of the two areas, and will depend upon the angle at which the hot emanations pass from the heated area. In accordance with a well-known law, the temperature of the body is found to be absolutely independent of the shape of the circumscribing spheres, which might be of any other shape than spherical, and is also independent of the position of the body in the interior of the cool area. It is only necessary that the radiations from the heated source should invariably be transmitted at the same angle to the cooler body. In practice the cold chamber consists of a double jacketed tube, with a cold water circulation resembling that of a tuyere, the diameter of which, however, was only  $\frac{1}{4}$  to  $\frac{3}{4}$  of an inch. This tube was placed in the chamber of the furnace which itself constituted the hot exterior area. If, now, the body A be at a known distance from the orifice, a definite relation existed between its temperature and that of the furnace. It is possible, on the other hand, to move it in such manner as to constantly retain it at a fixed temperature. In this case there will be a fixed relationship between its distance from the orifice and the temperature of the furnace. The investigations still remaining to be carried out relate to the choice of material of which the thermometric body A should be made. An illimitable number of substances might be found which, theoretically, might be of equal values, but in practice some were found to possess greater advantages than others.

Mr. A. McWILLIAM (Sheffield) said that it might be some little pleasure to their distinguished guest to know that the researches that had been conducted by Professor Arnold, for many of which he had had the pleasure of doing the pyrometric work, had been entirely done with the aid of the Le Chatelier pyrometer. He thought that most workers in connection with that matter would know that when the Le Chatelier pyrometer

came on the field, it was hailed by the metallurgist with much the same delight as was the cyanide process for the treatment of refractory gold ores. He had very carefully examined the exhibit of pyrometers downstairs, and he hoped to examine them a little further. With the recent extension of the facilities at the University College, Sheffield, they had had to go into the question of the various types of pyrometers. It might be because one was so well accustomed to the Le Chatelier, but for general work the Le Chatelier type was the one he found most convenient, and he thought that in that opinion he would be supported by a very great many practical workers who were endeavouring to use pyrometers in various ways on a large scale in the works. He had not prepared any remarks in connection with the paper. . . . He supposed that was because of the extreme familiarity with the work connected with them; but the words of Mr. Stead were worthy of note by those who were put in charge of pyrometers. In laboratory experiments one could endeavour to produce ideal conditions of work, as, for instance, in most of their own experiments they had a hole drilled into the steel, and the couple actually inserted into the very centre of the material, and then produced a vacuum in the containing vessel, but of course this was quite impossible in works practice. In a manner which had been very well brought out by Mr. Johns yesterday, that method might lead the way, and might in certain cases point out what the difference would be in application to works practice. Now those ideal conditions must, he was afraid, be very far departed from in all large works practice where the material had to be turned out at the rate of a certain number of tons per day or week. But it always seemed to him that the application of the pyrometer to practical work in a general way must be in somewhat the same manner as the tensile tests on metals used not only for the actual figures, but as a measure of the qualities of the metal, and so in the application of the pyrometer modifications might in many cases have to be made, so that one only knew that when one got a certain reading a certain result followed. Those who were about to take up the matter he thought ought to notice that some of the pyrometers were only available for telling the temperatures

of spaces. For example, the pyrometer, which must be protected by an air-tight tube, naturally could not be squeezed between two masses in the way Mr. Stead had mentioned, so that those who must have a pyrometer between the two masses of steel must leave that type alone. Although the temperature of the space and of the mass of steel were two very different things, in many cases, by taking the temperature of the space and finding it in different cases, allowing for the element of time for that material to reach the temperature or come near to the temperature of the space, much good work might be done with that particular type. Then a great deal of trouble was experienced in connection with those pyrometers by the deterioration of platinum and platinum-rhodium wires in the case of the Le Chatelier, or platinum wires in the case of some of the others; but his own experience was that in all cases where the wires had been suitably protected, they had a very considerable life. If any oxide of iron could obtain access to the wires, then their life was very much shortened. From these points of view, the question of taking the temperature of the space and taking the temperature of the actual metal, he thought those who were about to use pyrometers would be able to discover the type best suited to their needs. Some of the pyrometers he had not tried. One of them in particular seemed very ingenious at a casual glance; but a casual glance was very different to what it might be when one came actually to put it into use. At a cursory glance one of the optical pyrometers must be very good for the ideal they always look forward to, namely, the determination of the temperatures of the molten metal before it was run into the ingot or into the casting. That was a thing to which pyrometer makers ought, if possible, to apply themselves. The very able paper by Mr. Percy Longmuir had made the casting temperature of different metals, and particularly those metals in which the Institute was more particularly interested, a matter which must be gone into, and must be taken account of in the future with an even greater measure of care than in the best practice at the present time. The difference in the results with the same material at merely a different casting temperature was something very extraordinary. He thought that the pyrometer

makers ought, if possible, to keep their eye on perfecting a method of determining the temperature of molten metal as it ran into the casting or ingot. So far as determining the temperature of a space or of a piece of metal was concerned, he had found that the pyrometers of the Le Chatelier type were very valuable and gave very good results.

Mr. A. CAMPION (Cooper's Hill) said he could strongly bear out everything which Mr. McWilliam said as to the great convenience and simplicity of the thermo-couple method, and possibly, owing to having become so accustomed to its use, he might be somewhat biassed in its favour. In choosing a pyrometer it was most necessary to consider the use to which it would be put. It was a comparatively easy matter to obtain the temperature of the hot-blast or of a heated space, but to determine the temperature of a mass of steel was not quite so easy.

The thermo-couple undoubtedly took first place for determining temperature of material. It could be jammed close up against the mass or between two masses of steel in the furnace; and in this way it was possible to determine the temperatures of the steel sufficiently accurately for most works purposes.

He had himself used very successfully a thermo-couple with a portable form of dead beat galvanometer for taking temperatures about the works. He had used the Baird & Tatlock make both with and without recording arrangements. The reflecting galvanometer was too delicate an instrument to be used in a works unless it was placed far away so as to avoid the vibrations. This was not convenient, as it was important to be able to read the temperature on the spot. Another great advantage of the Baird & Tatlock form was that it could be carried about without upsetting the calibration of the instrument.

The new recording instrument, which was arranged so that the record was written with a pen on a chart attached to a drum, was a great advance, as the fluctuations of temperature could be seen during the whole period the instrument was set to run, and all bother of development of photographic films or paper avoided. The instrument was also sufficiently delicate to show the critical ranges in steel. It was only necessary to set the drum to revolve at a quicker speed to obtain perfect cooling curves.

The great drawback to the thermo-couple, and also the resistance pyrometers, was the failure of the pokers, especially if they should happen to have a blow whilst subjected to a high temperature. In order to obviate this, a water-cooled tube for holding the couple had lately been designed by Mr. A. Hill of Glasgow.

He hoped that before very long it would be possible to find a method of determining very high temperatures; at present the melting-point of platinum was the limit.

The Uehling pyrometer was free from that objection; but it was only suitable for determining the temperatures of heated spaces. It was also a very permanent instrument, and if it should happen that several instruments were fixed near together, it meant a lot of trouble and expense moving them in the event of alterations becoming necessary. In fact, it would be a matter of consideration whether it were better to move the works or the pyrometers.

He thought that whatever form of pyrometer was used it would be generally admitted that to Professor Le Chatelier great honour was due for having discovered the thermo-couple. It had undoubtedly been the foundation of the methods of modern pyrometry.

Professor HENRY LOUIS (Newcastle-on-Tyne) wished to draw the attention of the committee to what looked to him like the omission of an entire group of pyrometers of which he personally could speak very highly—namely, those pyrometers which acted by fusion. As an example of what he meant he would instance a pyrometer which he was very much in the habit of using, namely, the Seger Cone. It was useful for many practical purposes in metallurgy where one wanted to determine the temperature of a furnace space; for this purpose if one got anywhere within  $50^{\circ}$  it would probably be near enough for practical purposes. For such practical work he had used the Seger Cone with much advantage. There were other similar methods, such as the use of alloys. He need hardly remind the members of the old rough and ready practice when low-blast temperatures were used, of seeing how soon a bar of zinc or a bar of lead cut with the hot-blast at the tuyeres. He wished to draw attention to what seemed an omission of that entire group of methods

which were very valuable for practical purposes, though they might not have the scientific accuracy which some of the better instruments had. He felt that it was not right that the discussion should go on without attention being drawn to that very useful group.

Professor T. TURNER (Birmingham) wished to add a word or two in support of what Professor Louis had just said. They had had a considerable amount of experience in pyrometric work in connection with the pottery industry, and there was no doubt that the use of the Seger Cone in pottery kilns had been one of the greatest advances in recent years; and in this connection the improvements introduced by Mr. Watkins and also by Mr. W. Jackson might be mentioned. Both of these gentlemen had, in turn, been teachers of the Staffordshire County pottery classes. Their patents would be found in the list prepared as a supplement to the Report of the Committee. He thought that they were all very much indebted to the committee for bringing before them in so clear a manner a summary of the work which was being done on that subject; but he was reminded, when seeing the multiplicity of appliances, some of which were very simple and some were much more complex, of a story which he thought Tyndall told of Faraday. Faraday was appointed, with a number of other distinguished physicists, to go round the British Isles and examine and report to Parliament upon lighthouses. Some of the members of the party started with large impedimenta and with photometers which were of most complicated construction, and wondered what kind of apparatus Faraday, their great leader, would employ, but they saw nothing. When they came to take their first observation, however, he produced a scarf pin which had a bright knob, and, by examining in that small silver knob the intensity of the two lights which had to be compared, and knowing the distance of the two points, he was able to get a result which was at least as accurate as those given by the photometers which were carried by the other members of the party. It was very important, whenever possible, to adopt simple methods for the measurement of high temperatures. Just as simple organisms in biology were more permanent than those which were more complex, so, other things being equal, the



simplest means of measuring high temperatures would, no doubt, remain. He had introduced a modification of the method of determining temperatures by melting points, for the use of students at the University of Birmingham during the past year, and it had been worked with considerable success. He might just indicate how it was done. The object was to determine temperatures between about  $400^{\circ}$  C. and  $1200^{\circ}$  C. without the use of any apparatus or any expense. They started with substances of well-known melting points; preferably with metals, because those could be obtained in every laboratory, and were, of course, cheap and inexpensive—tin, lead, zinc, antimony, silver, and copper were used, while other metals could be added if required. A number of samples were taken and were placed in order on a small support made of fire-clay; cupels could, however, be used if preferred. Let it be supposed that they wished to determine the melting-point of three alloys, or of three salts, which he would call A, B, and C. These are placed on the fire-clay supports, together with about six fragments of different metals. The little appliance was now put into a gas muffle. Starting quite cold, the burner was then lit, and at the same time a stop-watch was started. The moment at which each substance melted was noted, and from these observations a curve was constructed having temperatures for ordinates, and time for abscissæ, as shown in Fig. 31. Provided these observations were made with reasonable care it would be found that the curve would be perfectly uniform. As the times at which the other substances which he had mentioned (A, B, and C) had also been noted, it was now easy by a very simple construction to ascertain the melting-point of each. The melting-points of several bodies could in this simple way be determined at once. It was a simple process by which a student, the first time he was put to use it, could get reasonably accurate results. In doing an experiment of that kind the student learned many things. He had to watch the furnace the whole time. He therefore learnt the appearance of the various temperatures of the furnace; he learnt the melting-points of the metals and of the materials he had employed. He had also learnt the relative value of different increments of temperature. He found that the first increment of  $100^{\circ}$  cost him say 1d., but as he proceeded the cost of the

last increment of  $100^{\circ}$  in temperature cost him perhaps 10d. or 1s., so that the higher the temperature the more money it cost for equal increments. There was also an important point. In many forms of apparatus which were introduced, as they came to a higher and higher temperature they got the readings crowded into a shorter and shorter space, and they became much more difficult to determine; but by this method the lower temperatures were crowded together and the higher temperatures were wider and wider apart, so that it was perfectly easy to separate say, the

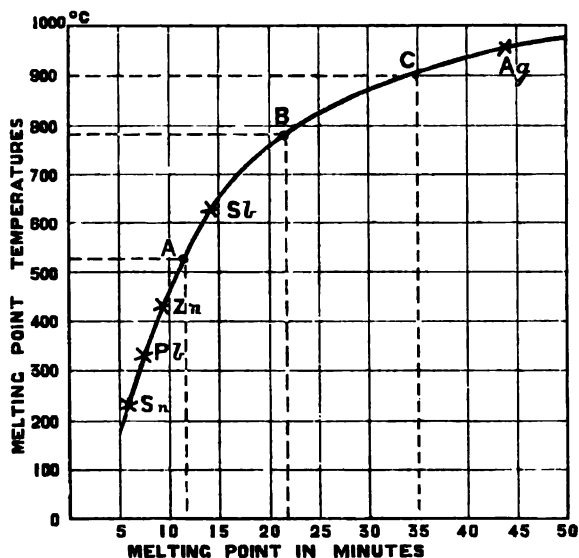


FIG. 31.

interval between  $900^{\circ}$  and  $1000^{\circ}$  into quite a wide range if that were desired. The student also learned that many of the melting-points given in the text-books of a few years ago were wrong. If one took potassium carbonate, sodium carbonate, or other well-known salts the melting-points of which were given on what appeared to be good authority as being over  $1000^{\circ}$ , it would be found that they melted before silver melts, and therefore one could not doubt that the points as formerly given were erroneous. The method described had been checked by putting into the muffle the ordinary Le Chatelier pyrometer, and it was found that the two curves thus obtained agreed so nearly that

one curve practically covered the other. They had, therefore, to adopt a different scale; the first curve was read from the bottom, and the other from the top, and started two minutes afterwards, and then one got two similar curves one behind the other, the one being determined by the Le Chatelier pyrometer, and the other by the simple means which he had mentioned. There was another application for an idea of that kind, and that was that it could be employed to calibrate a pyrometer. Suppose one wished to calibrate the Le Chatelier pyrometer. Instead of having a number of separate observations of melting-points one could, if desired, calibrate the pyrometer with sufficient accuracy for many purposes by one experiment. He thought the members of the Institute would be interested to know of a simple method such as that.

Mr. J. M. GLEDHILL, Member of Council, said he had had considerable experience in the use of pyrometers. With reference to the remarks of one speaker, who spoke of 50 degrees of temperature as being quite near enough for all practical purposes, that almost compelled him to say that that was not the case in many things which they had to do with at their works in steel. That was notably the case in the manufacture of armour plates. He did not propose to give an outline of the manufacture of armour plates, but on the use of the pyrometer in the latest description of armour plates; it was absolutely impossible to carry out any stage of manufacture with any degree of success only by pyrometers. There were probably six or eight different temperatures which an armour plate had to be taken through, and they were all critical temperatures. It was imperative if one wished to get a successful result, a successful ballistic resistance from the plate, to get out of the crystalline structure into the fibrous, and as every plate according to its analysis differed ever so slightly it became necessary, in order to get out of the crystalline condition, to have a different temperature for each. With a temperature of 1600, 1700, or 1800° Fahr. one must work from something between 10 to 20 degrees up and down a given temperature, according to the analysis of the steel being dealt with. They had a great many pyrometers of different descriptions to work to

that accuracy. They had the Le Chatelier for some time, and whilst admitting the great ingenuity of that pyrometer, and paying a worthy tribute to its distinguished inventor, they did not find it was practical to get on with their class of work with any rapid progress. Then they also had the Baird and Tatlock pyrometer, but they finally came down to the sweet simplicity of the Siemens water pyrometer—the ball pyrometer. Nothing could be more simple. He had no doubt that the members had all seen it downstairs—a can containing a known volume of water. A small iron ball of known weight was brought in contact with the forging or the article one wanted to know the temperature of, and was then put into the water, and the heat of the water rose according to the temperature of the ball. One could get with the water pyrometer within 20° Fahr. up or down with a temperature of anything like 1600 or 1700 degrees. So much had been taught them by Mr. Stead on the mysteries of steel that one knew that one could only get successful results by observing with accuracy the temperature; they could no longer judge by colour or old-fashioned methods; they must use pyrometers. And he strongly recommended that simple little instrument if they wanted accuracy and speed in workshop practice.

Mr. B. H. THWAITE (London) said that some twelve years ago, in a paper contributed to the Iron and Steel Institute,\* he had explained an optical pyrometer which he could recommend for all purposes which were required for testing the temperature of a bath of steel. One compared the luminosity of the bath by the temperature of the specific luminous flame of pentane or acetate of amyl, and one could by a comparatively simple calculation obtain the temperature of any incandescent mass of metal. He recommended Professor Le Chatelier's pyrometers also, which he had had the privilege of introducing into this country through the British press seventeen years ago.† The combination of the two instruments would satisfy any works

\* "Notes on Fuel and its Efficiency," by B. H. Thwaite, *Journal of the Iron and Steel Institute*, 1892, describing the Noul and Mesuré and the Cornu-Le Chatelier optical pyrometer.

† Vide article on "The Thermo-Electric Measurement of Elevated Temperatures," *Engineering*, 1887, vol. xliii. p. 239.

demands. For determining the fusing point of metals he would prefer the optical instrument, and for blast temperatures, and gas and space temperatures, the electrical pyrometer of their distinguished guest, Mr. Le Chatelier. Reference might have been made to the pyrometer introduced by Mr. James Murrie of Glasgow, which was a very useful instrument in its day. It could be relied upon for temperature measurements of closely approximate accuracy. It worked by the volatilisation of mercury. Mercury was volatilised and set up a pressure, and the pressure rotated a needle on a graduated dial, and it would register up to  $1400^{\circ}$  Fahr. The Murrie pyrometer was a very simple and easily applied thermal measurement instrument, and he thought some reference might have been made to it. He would ask Mr. Le Chatelier what his experience was with regard to deterioration. Mr. Le Chatelier had informed him that he considered there was no coefficient of deterioration required for the ordinary service of his beautiful instrument.

Mr. ENOCH JAMES (Cardiff) said that being indirectly, perhaps, the cause of the first application of the recording pyrometer to blast-furnace purposes, he might be permitted a few words to give a historical fact which had not yet been made mention of to the Institute. The late Past-President, Professor Sir W. C. Roberts-Austen (then Mr. Roberts-Austen), brought a class of students to visit the Cardiff works, and was very much taken up with a small instrument which he (Mr. James) had designed for recording the time at which the stoves were changed. Their Past-President, Mr. Edward P. Martin, asked Mr. Roberts-Austen if he could not apply some method of recording the temperatures as obtained by the Le Chatelier pyrometer. The Professor set to work, and produced a photographic apparatus, and when it was completed it was erected at the works. It was not long in operation before he (Mr. James) discovered two deficiencies. One was that one could not see until the next day what was the temperature of the blast, and one wanted to know at the time. Another thing was that the reading of the pyrometer was from right to left, and not from left to right, as was the way they were brought up to read. To remedy this he suggested a deflecting mirror, which

transferred the ray of light to a known scale on the front of the instrument, greatly adding to the value of the instrument for practical blast-furnace managers. He also suggested the alteration of the direction, and the motion of the drum, which made the reading like other ordinary English reading. He thought that blast-furnace men had much to thank Professor Le Chatelier for his most useful instrument, which had somewhat modified their great difficulties.

Mr. WELDON HANSON (Stockton-on-Tees) said they had heard the opinions of the university professors on the pyrometers, and he should like very much to hear what works chemists had to say about them. He did not think that he had heard one of them yet, so he would therefore give his opinion as a chemist. Before starting he would like to remind Professor Turner, with regard to the method of determining temperatures by observing the melting-point of different metals, that Sir Lowthian Bell had used this method thirty years ago in his reduction experiments. At the Clarence Ironworks they had used almost every form of pyrometer. He was glad that Murrie's pyrometer had been mentioned, because they had tried it, and it had worked very well, but of course it was out of date now. Frew's pyrometer was also worthy of mention, although it had some weak points, all of which have been overcome, and Frew's method brought to a fine state of perfection in Uehling's pyrometer. They had had the Le Chatelier pyrometer working for the last fourteen or fifteen years. Sir Lowthian Bell saw one in use at the Mint, and immediately adopted it. At first it was carried in a sedan chair to the place where the temperature was required; afterwards it was fixed in a dark room in the office, with wires leading to each furnace through a switch-board. He had heard many times that the Le Chatelier pyrometer was too fragile for works use, but he could assure them that such was not the case, as he had ample opportunity of observing when they carried it from place to place in the works. One day his assistant got his legs entangled in the wires, and pulled the whole apparatus on to the floor; the glass cover of the galvanometer was broken, but the galvanometer itself was none the worse for the accident. It was as good to-day as the day they

got it. The Le Chatelier was in his opinion the best pyrometer for works use. They also had two Roberts-Austen recording pyrometers which were very useful in special cases, but they were troublesome for daily use on account of the time required for developing and marking off the curves, also the impossibility of seeing the curve till the following morning. As a recording pyrometer there was none to beat the Uehling.

The average life of a Le Chatelier thermo-couple was three months, sometimes one might last as long as seven months, but that appeared to be the maximum. As well as the fixed Le Chatelier which he had just mentioned, they also had a portable one with the galvanometer mounted on gimbals. This they found to be exceedingly useful for occasional work. They also had Wiborgh's air pyrometer, but found it too fragile for works use; the porcelain bulbs soon got broken.

Sir LOWTHIAN BELL, Bart., Past-President, said that he had used the Siemens pyrometer, for the simple reason that at that time he could get no other. He could speak with the utmost confidence of the general accuracy of that very simple piece of apparatus. But they required a good deal more than that; they required to be able to ascertain what the temperature was at the various points of the blast-furnace immediately. Mr. Le Chatelier's pyrometer entirely fulfilled those conditions. They had a wire introduced into the blast which gave the temperature in an instant of the air, and another showed the temperature of the escaping gases as they issued from the furnace. He would be very sorry indeed not to have the means of registering the operations of the blast-furnaces by the use of Mr. Le Chatelier's very simple apparatus.

Mr. WALTER ROSENHAIN (Birmingham) said he wished to say a word or two on the pyrometers from the works chemist's point of view. For some three years he had been endeavouring to use the Le Chatelier couple combined with the Roberts-Austen recorder for recording the temperatures of furnaces ranging between 1300° and 1500° C. The point he was aiming at was continuous recording for a month together. The trouble

which was encountered there was that although the couples lasted very well for a short time they soon gave out. If one left a couple in the ordinary way just inside the porcelain tube in a furnace, particularly if that furnace were working in a reducing atmosphere, in the course of half an hour the couple would actually break. He had tried all sorts of things to get over that. It was well known that this was due to the action of the furnace gases upon the platinum metals. There was one observation which seemed to differ from the statement in the account of the pyrometer in the report before them; it was said that the rhodium couple was more durable than the platinum-iridium. That struck him as curious, because what he had found was that it was the pure platinum wire which suffered very much more rapidly than the platinum-iridium alloy! He had two platinum-iridium alloys, one 30 per cent., and the other 10 per cent., and proposed leaving pure platinum out altogether. So far from finding the iridium undesirable he had found it was rather the other way. The great difficulty was protection from the furnace gases. One could make that protection as perfect as one pleased by interposing a layer of some, he would not say refractory material, but some material which melted at the highest temperature; it formed a viscous mass, which was a very great obstacle to the passage of the furnace gases, and prevented them acting upon the couple. But that introduced a serious lag. The couple ultimately got the temperature of the furnace, but it followed at a very considerable distance of time—something like a quarter of an hour. It did not really reduce the temperatures which the couple indicated. He had tried to check it by the Seger Cones. Where one had to measure temperatures anything over  $1300^{\circ}$  it seemed to him that to put anything in the furnace at all, be it a thermo-couple or a Uehling tube, or an air-bulb, was perfectly hopeless if one wanted to do it for more than a few minutes at a time. Practically everything went if one left it there for any length of time and exposed it to the actions which were taking place. He thought that some method of optical pyrometry was the only solution. With the lower temperatures which were dealt with in annealing, hardening, and so on, there were any number of methods



which were satisfactory. One of the most convenient, in fact he would say *the* most convenient, was the Callendar recorder. The advantage over the Roberts-Austen form of Le Chatelier pyrometer was that one could not only see the temperature at every moment—that could be done with the others also—but one could see the record at every moment, and one did not have to do anything in the way of development. One could find a record for several hours at any time by looking at it, because the instrument recorded in pen and ink. All those instruments were delicate in the sense that they would not stand corrosion; one must protect them from furnace gases. So far from agreeing with the gentleman who said that a galvanometer was no worse for being dragged about by an assistant's legs, he would say even leaving it standing still in an ordinary furnace house where the atmosphere was not very suitable to the prolonged life of brass, was quite sufficient to spoil an instrument in a short time. He had that painful experience with one or two galvanometers, so that now he went in for air-tight cases and kept them under lock and key. Even then it was difficult, because one had to get at them occasionally, and a slight amount of corrosion of a suspending wire was a very serious matter. The disadvantage of an electric pyrometer was the mechanical breakage, which unfortunately was very apt to occur when handled by workmen, as it must be if it were to be a success.

There was one observation which he wished to lay before the Institute, because it was rather interesting. In the course of experimental attempts to protect the Le Chatelier couple from the action of the furnace gases he had tried embedding the couple in fire-clay direct, simply laying it in the fire-clay while the fire-clay was still damp, moulding it and burning it in a proper kiln and putting it into the furnace. He thought that would be a good protection, but the arrangement behaved in a very curious way. First of all it corroded through in a very few minutes, and then it acted as a little battery. There was a very considerable electro-motive force for the first few minutes, which then gradually fell off. If one broke the circuit and let it rest for a few minutes and then started it again, the current was again at a maximum and fell down again. It was simply

behaving as an ordinary primary battery with polarisation of the electrodes. At that temperature, about  $1500^{\circ}\text{C}$ ., the clay was acting as an electrolyte and conducting electricity, and its corrosive action upon the platinum-iridium wires was quite sufficient to set up a distinct current, which one could measure on the galvanometer supplied with the instrument. He thought that great caution had to be used when one attempted to insulate electrical conducting wires by means of so-called refractory materials, because their power of conducting electricity at those temperatures was very considerable indeed. That had, no doubt, led to a good deal of error and discrepancy.

Professor J. O. ARNOLD (Sheffield) said that those who had spoken seemed to have divided themselves into two classes, the professors and the works chemists. With their permission he proposed to appear in both characters. He had used a Le Chatelier pyrometer for fourteen years in the Metallurgical Department of the Sheffield College, and had submitted it to exhaustive tests, and the more he knew it the more he liked it. The system had been to have a central station, because the pyrometer had to be used both for research purposes and for practical furnaces purposes. It was a very delicate instrument; each millimetre was equivalent to about  $3^{\circ}\text{C}$ . Then the whole of the furnaces for recalcination and so on were coupled up with it; but outside they had the boilers, the Siemens furnace, the crucible furnace, and the annealing furnace, and these were also connected with the central station by overhead wires, some of them a hundred yards long. Then, of course, they had a switch-board, and they could switch on the temperature of any furnace; that arrangement had been most satisfactory. They had got very good results in connection with the regenerators of the open-hearth furnace, particularly on one occasion. It was decided it was only necessary to put in one new regenerator; but when they came to test them with the pyrometer afterwards they found they had made a very great mistake—the efficiency of the new generator was very much greater than the old one. He agreed with a previous speaker that so far as they had gone for ordinary work the Le Chatelier was the best pyrometer and the Uehling was the best recording instrument, so far as he could

1904.—i. M

judge. There was one other point in connection with some of the remarks made by Professor Turner. He could only say that his colleague, Mr. McWilliam, and himself had made hundreds of calibrations with the Le Chatelier pyrometer, and they did not want to go to any new methods. Boiling sulphur, boiling selenium, and normal potassium sulphate time after time gave a perfectly straight line. And he was perfectly certain that the published boiling and melting points of those substances were correct, and that they gave an extremely accurate calibration.

Mr. R. A. HADFIELD, Member of Council, said that in drawing up the paper of course it had been impossible to include every known method of taking temperatures, as for instance the Seger Cone, which had been referred to. Before the paper was issued to the members he thought there would be certain additions made, and then he hoped the paper would be the most complete which had ever been published on that matter. He need hardly say how highly honoured the Institute was that morning in the presence of Professor Le Chatelier. It was through him that they had had a most remarkable advance in the art of treating metal. The more they studied the question the more important they found that particular branch of research necessary for improving their processes. They had heard the remarkable statement of one of the leading metallurgists of this country, Professor Arnold, who had stated that he had Le Chatelier pyrometers for fourteen years, and they were as good to-day as when he first used them. He thought that was indeed the highest testimony to a remarkable work accomplished by the French scientist. He would also like to say that he had hoped that the pyrometer makers, who had taken an enormous amount of trouble in bringing their instruments to the Institution, would feel that they were rewarded. When the idea was first suggested, largely by his friend Mr. Stead, he was asked to assist in getting that work in order, and he could only say what a pleasure it had been to both of them to see the excellent practical work which they had downstairs in the way of the instruments shown. The Institute was very much indebted to all those gentlemen for the trouble they had taken in bringing their instruments there. He hoped that they would know that they had yet to get a perfect

instrument. He had had the pleasure of a chat with several of them yesterday, and had pointed out one or two practical difficulties which his firm had found. He was sure that the admirable way in which their efforts to put further information before the members had been received would be an encouragement to them to go on and perfect their instruments. No doubt for certain practical work they wanted a pyrometer easier to handle. The working parts wore out more quickly than they should do. He thought the gentlemen concerned in the manufacture of those instruments would be encouraged to go on and improve their instruments still further. He was delighted to say that to-day Great Britain was no longer dependent on the standardisation of its various scientific instruments, this work is now carried out at the National Physical Laboratory. Dr. Glazebrook was present that day, and he must be congratulated on the admirable work he was doing by helping all the instrument makers and also the practical worker to get the various points of pyrometers standardised. The members present must all be aware of the fact that they could now get their wire standardised or calibrated for all scientific or practical purposes by Dr. Glazebrook at the National Physical Laboratory. Only a few years ago that had to be done in Germany, but he was now happy to state that they could say it could be "made in England."

The PRESIDENT moved that a vote of thanks be given to the Committee, Mr. Hadfield, Mr. Stead, and the Secretary, for the very decided success of the exhibition of pyrometers, and also a vote of thanks to the exhibitors and to the Council of the Institution of Civil Engineers for their help.

The resolution was carried by acclamation.

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### CORRESPONDENCE.

Mr. A. PATTERSON (Cardiff) writes that the Roberts-Austen pyrometer as used at the Cardiff blast-furnaces is a very delicate instrument, requiring skilled attention, and the vibration

caused by a locomotive working near would seriously affect the accuracy of the record. The thermo-couples soon become brittle and often break where most exposed to the heat.

On account of these and other defects referred to in the meeting, Mr. W. Evans decided to adopt an improved and patent pyrometer, that was easily kept in order, that was not expensive in first cost, and that should give a record for twenty-four hours which could be seen at any time.

This type of pyrometer has been in use at these works for over two years with very satisfactory results.

The pyrometer is made of a couple of bent iron wires 5 feet long and 24 B.W.G., sheathed in fireclay insulation, and mechanically protected by a casing of steam tube.

Iron wire couples only have been used at the Cardiff works for a temperature of up to 1500° Fahr. on account of the cheapness of the wire, and the ease in which they are changed, which takes place every few days. For high temperatures it would be desirable to use platinum or some wire with a higher melting point than iron.

The chief reason for adopting iron wire couples is, the high increase of resistance of iron to flow of electricity as the temperature is increased and the consequent drop of the voltage, which on a temperature of 1000° Fahr. to 1500° Fahr. varies from 2 to 3 volts. The current is from 0.125 to 0.135 amperes.

The total pressure for working the pyrometer is about 6 volts.

Calibration is affected in the usual way, by metals of a known melting point and noting the number of degrees of deflection on a low reading recording voltmeter, at the various temperatures due to the drop of voltage caused by the increased temperature.

Having obtained the degrees of angular deflection, they are transformed into degrees of temperature.

Calibration once made is permanent, and does not require to be repeated. The pyrometer may be easily shifted to various parts of the works.

Mr. P. PELLIN (Paris) points out certain omissions from the Report, amongst which he enumerates the Le Chatelier optical pyrometer, the Le Chatelier galvano-pyrometer and thermo-electrical couple, a sub-registering modification of the latter, and the pyrometrical glasses, with thermo-electric grating, devised by

C. Féry. The first named depends upon the fact that it is possible to determine temperatures by observing the intensity of the red rays emitted by an incandescent body. The pyrometer itself is a modification of the Cornu microphotometer, and consists of a telescope which carries at one side a small flame for the purposes of comparison. The reflection of this flame is projected on a mirror placed at an angle of  $45^\circ$  in the principal focus of the telescope. The telescope is focussed until both the object viewed and the flame used for comparison appear of equal intensity side by side on the screen. The extreme sensitiveness and rapidity with which the rays vary in intensity, between about  $600^\circ\text{C.}$  and  $1800^\circ\text{C.}$ , render the apparatus one of great accuracy, since between this range the intensity varies a millionfold, so that errors of adjustment or of observation entail but fractional errors as regards the equivalent temperatures. Professor Le Chatelier has also devised two strong galvanometric pyrometers, one for use in works laboratories, and another furnished with a self-recording arrangement. Mr. Pellin likewise draws attention to Féry's pyrometrical telescope, which is based upon the law discovered by Stefan and defined by Kirchhoff, according to which the amount of heat radiated by a dark body, or by an aperture in a furnace urged to a high temperature, is proportional to the fourth power of the temperature of that body or furnace. A dark body is defined as one which emits all the heat rays in normal proportion on being raised in temperature. This law is applied to the construction of an optical pyrometer, in which use is further made of the fact that above  $900^\circ$  the quantity of heat absorbed by fluorspar bears a constant ratio to the amount of heat transmitted, with the result that the determination of the latter renders the former easily determinable. The relative scarcity of pieces of fluorspar fit for lenses has led, in the cheaper forms of the instrument, to the use of a special optical glass, the images given by which have been standardised by one with a fluorspar objective. The price of the works form of apparatus giving readings up to  $1600^\circ$  is between £16 and £17.

Mr. AXEL SAHLIN (London) wrote that the pyrometer had been discussed from the scientific point of view, from the point of view of the steel melter, the ironworks manager, and from that of the

ironworks chemist. There was, however, another class of men from whose standpoint it might be well to study the requirements of a good pyrometer, *i.e.*, the practical blast-furnace foremen or keepers, the men who had to read the pyrometer during dark nights, in storm and rain, in heat and cold, and act on the readings promptly, and as the blast-furnace might at the moment require. It was evident that for these men a pyrometer requiring calculations in order to obtain the temperature in plain figures had no practical value, and even a pyrometer which gave the temperature of the blast at a certain point and at a certain time, or one which in addition recorded the temperatures at that point continuously during the previous 24 hours, was, though valuable, not an infallible guide.

At least, in making grey iron, the rule, employing expensive fuel, was to give the furnace all the heat which it would take, or which the stoves would give. They might, as was usually done, from experience arrive at the temperature which a certain furnace, under ordinary conditions, would take without hanging, but the conditions would from time to time change without giving them notice that such a change was preparing or taking place inside of the furnace. The pyrometer could give them no warning, and the fact that the number of degrees read on it were below the average under normal conditions was no warrant that the heat was not in excess of what was required or suitable for the furnace at the particular time.

What the practical blast-furnace foreman needed, in addition to and in connection with a plain and simple pyrometer which could be instantly read, was an instrument which would tell him whether the furnace was getting too much, just sufficient, or too little heat at any given time, and which would, therefore, enable him at the right moment to adjust the blast temperature to prevent threatening interruption of the regular working.

The chairman had rightly called attention to the fact that it was by a free exchange of experience that they secured general progress. He (Mr. Sahlén), therefore, would describe a blast-furnace pyrometer, which did not give temperature in degrees but told whether a blast-furnace required more or less heat. The exact temperature could and should, in addition, be recorded by any one of the excellent pyrometers which had been described in the paper they were discussing.

From the day of his (Mr. Sahlin's) earliest experience with blast-furnaces he had now and then, on reaching the works in the morning, been told by the foreman or keeper that the furnace was working a "little stiff." Just how stiff the furnace was working, or how long the obstructions (*i.e.*, the stiffness) had been forming, the workmen never could tell. Nor did the record of the blast pressures kept in the blowing engine house give a

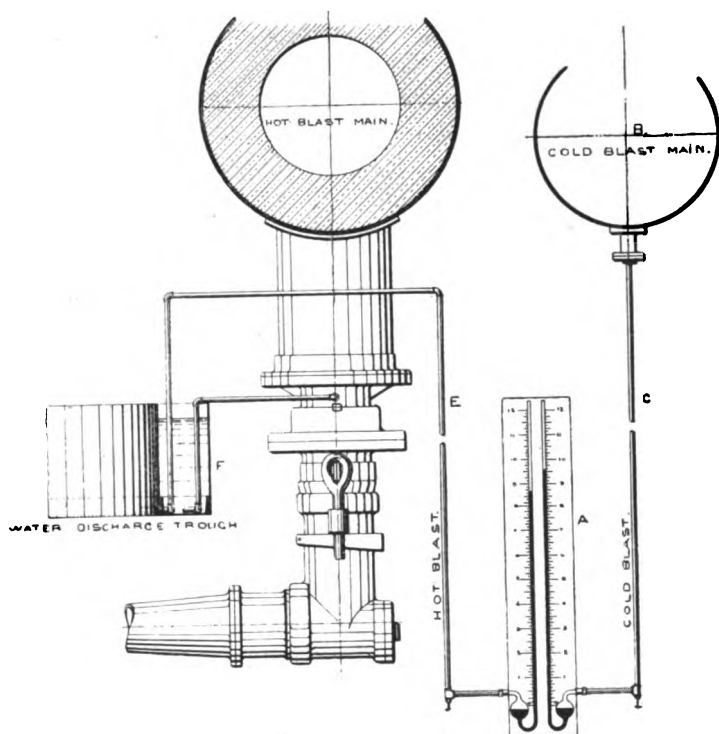


FIG. 32.—Sahlin's Blast-Furnace Indicator.

sufficient guide, because the resistance of the furnace would necessarily change with the fineness of the ore, the composition of the slag, and alterations in the mixture. He was therefore led to devise a very simple instrument, which had given excellent satisfaction, and which he believed was original in its application. This instrument consisted of two open mercury gauges, A, placed side by side over a graded scale marked in lbs.,  $\frac{1}{2}$ ,  $\frac{1}{4}$ ,  $\frac{1}{8}$  lbs. of mercury column. The bulb of one of these gauges was connected



by pipe C with the cold-blast main of the furnace, B. The bulb of the other gauge was similarly connected with the interior of one of the nozzles of the hot-blast pipe, D, to which the gooseneck for a tuyere was attached. This connecting pipe, E was cooled by being partly immersed in the discharge water trough of the furnace, F (Fig. 32).

As soon as the blast was turned on the furnace, it was noted that the cold-blast gauge showed a pressure somewhat higher than that shown by the hot-blast gauge. If the furnace was hanging, and therefore would not take the blast, the two pressures would be practically equal. If the furnace was working regularly the difference in height of column varied for different furnaces from  $1\frac{1}{2}$  inches to 2 inches. If the zone of combustion had risen too high in the furnace, the difference between the two gauges might be up to  $2\frac{1}{2}$  inches or 3 inches. They had soon found the proper difference in pressure between the two gauges, which corresponded to the most normal working for each separate furnace. They had also found that if they increased the blast temperature, the difference between the two mercury columns was decreased. If, again, cold blast was admitted, the difference was rapidly increased. The difference in height of mercury columns would at any moment indicate just how stiff the furnace was working, or, in other words, how much resistance the furnace offered against the blast.

Their practice was for the keeper and stove tender frequently to observe the mercury gauges. If, as was sometimes the case after casting, the furnace would not take the blast, such a fact was at once indicated by the gauges. To restore normal conditions, it generally sufficed to open the cold-blast connection for a quarter of an hour.

In blast-furnace practice it was all important to judge correctly and act promptly. It was found that this easily read and understood instrument for ascertaining the working of the furnace gave a more reliable guide for conducting the operations than the reading of exact temperatures.

There would be little difficulty in arranging a similar instrument which would make graphical continuous records of the two pressures, thus enabling the scientific manager to make history; but for the man who actually operated the furnace, what was going on and what was going to happen was more interesting

than what actually did happen 24 hours ago. The latter they could not change: the former they were at all times endeavouring to ascertain and to control.



FIG. 33.

Dr. A. WEISKOPF (Hanover) considered that of the pyrometers shown that of Wanner was of special interest to the metallurgist. The results were based on a definite physical law, and

consequently the temperatures given were absolutely trustworthy. The lowest temperature that could be measured was  $900^{\circ}$ , and an upper limit did not exist. The ease with which the apparatus

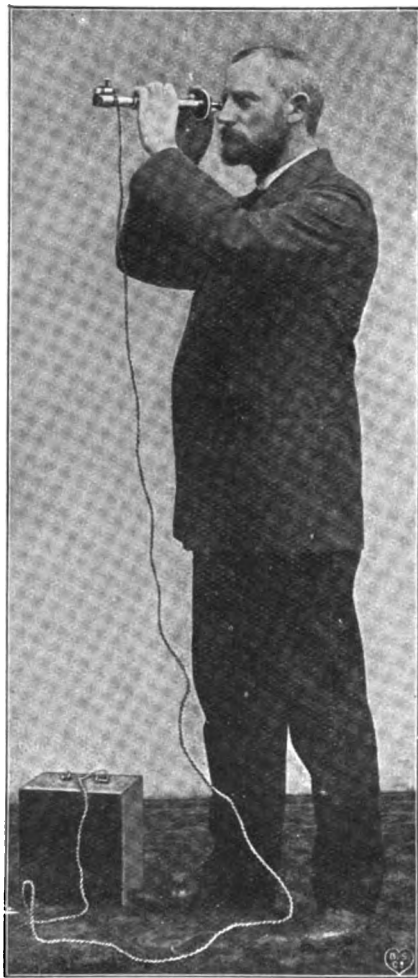


FIG. 34.

is employed was shown in the accompanying illustrations (Figs. 33 and 34). The pyrometer could be transported with facility, and the accumulated battery weighed only 15 lbs. The apparatus

was set at a given standard (see Fig. 35), which after several days must be checked with the aid of an amylacetate lamp

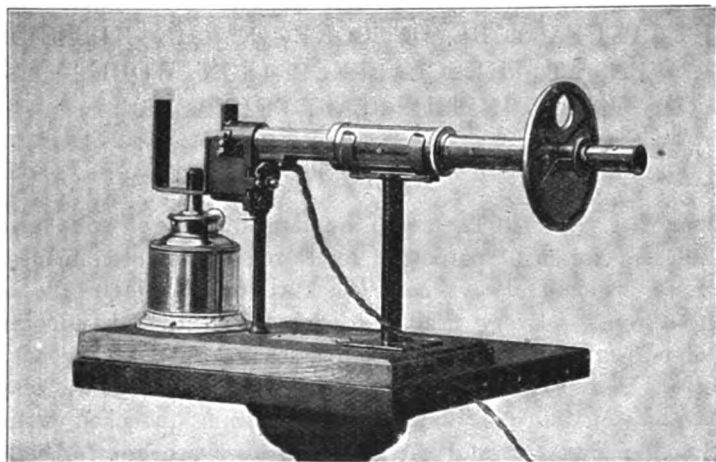


FIG. 35.

supplied with the instrument. Determinations had been made with the instrument at several German ironworks either by the management or by the writer. The results were appended:—

*Temperature Determinations with the Wanner Pyrometer.*

Blast-Furnaces.	Hoerde.	Osnabrück.	Ilse.	Witkowitz.
	Degrees.	Degrees.	Degrees.	Degrees.
<b>Pig iron—</b>				
At blast-furnace, hot . . .	1317	...	...	1225
"    "    cold . . .	1284	...	...	...
On running out of mixer . . .	1260	...	...	...
On running into converter . . .	1240	...	...	1211
At tipping of converter . . .	1460	...	...	...
At solidifying . . .	...	...	1012	...
On running out of cupola . . .	...	1239	...	...
<b>Slag—</b>				
At blast-furnace, hot . . .	1402	...	1424	...
"    "    cold . . .	1370	...	1372	...
On running out of mixer . . .	...	...	{ 1390	...
On running into converter . . .	...	...	{ 1384	...
At tipping of converter . . .	1555	...	1230	...

The temperature of tapping an open-hearth furnace was found to be at Hoerde 1718°, and at Peine 1759°.

## THE MANUFACTURE OF COKE IN THE HÜSSENER OVEN AT THE CLARENCE IRON WORKS, AND ITS VALUE IN THE BLAST-FURNACES.

BY C. LOWTHIAN BELL (MIDDLESBROUGH).

BEFORE the year 1901, though numerous trials of coke made in different forms of patent or retort ovens had been made at Clarence, we had always come back to that made in the old beehive ovens. Every trial had proved that the dirty-looking "cinders" made in the newer apparatus were not as good as what we were accustomed to. It has been held that the black appearance of the coke was caused by its being quenched outside the coking chamber, and this certainly does account for retort coke containing, as a rule, more moisture; the recovery of the by-products has been blamed for the coke not working well in the furnace, but even retort ovens, without this adjunct, have, in our opinion, never made coke good for the blast-furnace. I think I shall prove that, with the Hüssener oven, we can make a coke giving as good results in the furnace as that made in the beehive.

At Clarence, the coal is delivered into hoppers, whence it is taken by a travelling belt to a screen and a Carr's disintegrator. All the coal is ground so as to pass through  $\frac{3}{8}$ -inch square holes. It is then washed on a Wood & Burnet washing belt made rather longer than is usual, the water from the main belt being allowed to settle, and the silt being re-washed.

The analysis of the coal before and after washing is:—

	Before.	After.
Ash . . . . .	10·42	6·42
Sulphur . . . . .	1·71	1·30
Volatile matter . . . . .	28·67	29·47
Fixed carbon . . . . .	59·20	62·81

These analyses are the average of the whole of the year 1903.

The highest ash dealt with has been 20 per cent., which was reduced to 9 per cent., and the coke contained 8 per cent.

During this period (52 weeks) we dealt with about 105,000 tons of coal, and the loss in washing was 10·61 per cent.—taking away from the coal 4·14 per cent. of its original coal. The shale, which is washed out, is continually being examined by being divided into “coal” and “shale” in a solution of a specific gravity of 1·5. 81·4 per cent. is found to consist of shale containing 27·5 per cent. of coal, which we think we cannot recover, and the remaining 18·6 per cent. is coal with 90 per cent. of coal in it, which may be considered as absolute waste, and can only be recovered at a very great cost.

The coal lost in the washing can therefore be divided into:—

	Per Cent.	
As coal . . . . .	1·77	} of the original coal.
As shale . . . . .	2·37	
	<hr/> 4·14	„

The loss as shale is attributable to the splint or stone coal found in one of the seams in Durham, the specific gravity of which prevents its being washed, so that this 2·37 per cent. may be considered as unavailable.

The coke made from the washed coal contains 8·18 per cent. of ash; made from unwashed coal it would contain 13·26 per cent. This extra ash, with the lime necessary to flux it, would mean 2·27 cwts. of slag more per ton of iron in the blast-furnace, and would require, to melt it, heat equal to that given by 0·35 cwts. of coke.

The coal coming from the washing belt is allowed to drain for about forty-eight hours before going to the ovens, when it contains on the average 10·60 per cent. of water. This quantity of water we consider an advantage even when not compressing the coal, as it causes the coking process to be performed more slowly, making the coke harder and more dense.

It is a very difficult thing to decide which is the best form of oven for the blast-furnace manager, and I fear that our experience is that of every one else, viz., that each oven that has ever been invented is infinitely superior to the preceding ones. I do not propose to say which particular form we took for our experiments before deciding which we should adopt, but simply to say that the colliery, from which we got our coke, is situated in the county of Durham, and thus the coal treated there was

similar to the coal raised at our own collieries. Sufficient retort-oven coke was bought to allow one of our furnaces to work on it alone for six or seven weeks. Samples were taken day and night, and similar samples were taken of coke from other collieries made in beehive ovens. The first series of experiments were on the volatile matter. Ten grammes of coke were heated in a closed vessel, and the resulting gas was drawn off by means of a mercurial pump.

The analysis of this gas was :—

Composition.	Turndale Coke.	Brancepeth.	Retort Coke.
	Per Cent. of Coke.		Per Cent. of Coke.
	Per Cent.	not taken	Per Cent.
CO <sub>2</sub> . . . . .	0·210		0·132
CO . . . . .	0·136		0·508
CH <sub>4</sub> . . . . .	0·005		0·093
H . . . . .	0·018		0·334
N . . . . .	0·071		0·153
Total weight of gas .	<u>0·440</u>		<u>1·220</u>

Experiments were then made to see the action of a regular current of CO<sub>2</sub> at different temperatures on coke made in various ovens. Samples (broken to the size of mustard seed) were placed in the tube of a Hoffman furnace, and through the tube were passed the wires of a Le Chatelier electric pyrometer. All air being driven off, the temperature was raised, and the resulting gas analysed to see what proportion had been converted into CO by dissolving the carbon of the coke.

At a Temperature of from	CO in gas.	CO in gas.	CO in gas.
Dega. F.	Turndale.	Brancepeth.	Retort.
1500 to 1549 . .	1	...	1
1550 „ 1599 . .	3	3·3	4
1600 „ 1649 . .	5	4·7	7·25
1650 „ 1699 . .	8	8·0	9·20
1700 „ 1749 . .	10·5	16·7	18·20
1750 and above .	15·2	19·0	29·10

The extra solubility of the retort may be due to its being in the oven for a much shorter period. Beehive coke takes from

72 to 96 hours to burn, and then it is often left in the oven for ten or twelve hours before being drawn, whereas in the case of retort coke the operation is completed in about 32 hours, and as the coke-maker is generally a manufacturer of by-products, he is anxious to get the oven drawn and re-charged, more especially as the first gas is richer than the last.

In order to prove that the same action as we had observed in the laboratory took place in practice, one of the Clarence furnaces was put on to these three cokes :—

	Turisdale.	Brancepeth.	Retort.
	Tons.	Tons.	Tons.
Iron made . . . . .	3345	5524	4698
	Cwts.	Cwts.	Cwts.
Coke used per ton . . . . .	22·67	22·75	23·77

Burden carried per unit of coke :—

	Units.	Units.	Units.
Ore . . . . .	2·116	2·095	1·738
Limestone . . . . .	0·564	0·565	0·508

The analysis of the coke averaged :—

	Turisdale.		Brancepeth.		Retort.	
	Per Cent.	Per Ton of Iron.	Per Cent.	Per Ton of Iron.	Per Cent.	Per Ton of Iron.
		Cwts.		Cwts.		Cwts.
Moisture . . . . .	1·43	0·32	0·82	0·19	2·80	0·66
Ash . . . . .	9·84	2·23	9·02	2·04	9·90	2·35
Sulphur . . . . .	0·99	0·22	0·88	0·20	1·08	0·26
Volatile matter . . . . .	1·08	0·25	0·74	0·17	2·47	0·59
Fixed carbon . . . . .	86·66	19·65	88·54	20·05	83·75	19·91
Total . . . . .	100·00	22·67	100·00	22·75	100·00	23·77

In these cases more coke made in the retort was required to make a ton of iron than was the case when using coke made in a beehive oven, and a considerable number of analyses have confirmed the opinion that the consumption of coke is increased in some proportion to the solubility of the carbon in  $\text{CO}_2$ , though we have not yet succeeded in finding the exact ratio.

Samples of the gas escaping from the top of the furnace were



taken, and also samples were drawn out at the level of the tuyeres when working on retort and South Brancepeth coke, in order to see if there was a greater loss in the quantity of carbon passing through the furnace in the former case than in the latter. Unfortunately, similar experiments were not made with the Tursdale coke:—

Carbon per Ton of Iron at Tuyeres.	Retort.	South Brancepeth.
By calculation . . . .	17·43	17·21
„ analysis . . . .	16·15	17·33
	<hr/>	
Loss . . . . .	1·28, or 7·34 per cent.	
Gain . . . . .	0·12, or 0·7 per cent.	

I may say here that one of the results of these experiments has been that we now, at Clarence, take as much notice of the volatile matter in the coke we receive as we do of the ash and sulphur. This enables us to tell whether the coking process has been properly completed, and is the more necessary when using coke made in ovens producing by-products, as the coke manufacturer is very liable to draw the oven before it is, to use the technical Durham term, “off.” The system employed by Mr. Hanson in the Clarence laboratory is as follows: The coke, very finely divided, is placed in a porcelain crucible, and on to it is poured some half-dozen drops of benzine. This crucible is placed inside a larger one, and the space between the two filled with roughly-ground charcoal. The crucibles are placed just inside the muffle until the benzine takes fire and is almost entirely burnt off, when it is put into the hottest part of the muffle (a temperature of about 1800° F.), and left for half-an-hour, when the inner crucible is weighed, the loss representing the volatile matter. In this way all air is driven off at a low temperature, and none of the coke itself is burnt.

A considerable number of similar experiments on coke from different ovens were made, giving results more or less the same, and we were obliged to go farther afield to find a suitable coke-oven. A visit to Germany brought to our notice the Hüssener oven working near Essen. In order to test thoroughly the capabilities of this oven, a considerable quantity of coal from the Tursdale colliery, washed and prepared for coking, was sent, and made into coke at the Hüssener works. Samples were taken

of the dry coke made from Tursdale coal, and brought back to Clarence for analysis, the result being—

Ash . . . . .	8.13
Sulphur . . . . .	0.33
Volatile matter . . . . .	0.27
Fixed carbon . . . . .	90.67
	<hr/> 100.00

The volatile matter in the coke was drawn off by a pump, and was found to consist of—

CO <sub>2</sub> . . . . .	0.076 per cent. of coke.
CO . . . . .	0.115   "   "
CH <sub>4</sub> . . . . .	0.005   "   "
H . . . . .	0.012   "   "
N . . . . .	0.067   "   "
Total per cent. of coke by weight . . . . .	<hr/> 0.275

The resulting gas, on passing CO<sub>2</sub> over the coke, was found to contain the following quantities of CO :—

From 1440 to 1499° F. . . . .	1 per cent.
.. 1500 .. 1549 .. . . .	2   "
.. 1550 .. 1599 .. . . .	5   "
.. 1600 .. 1649 .. . . .	8   "
.. 1650 .. 1699 .. . . .	11   "
.. 1700 .. 1749 .. . . .	15   "
Above 1750 .. . . .	25   "

Both from its appearance and the results of a considerable number of similar experiments, we came to the conclusion that coke made in this particular form of oven was better for our purpose, and we decided to build sixty ovens at the Clarence Works. These were started in January 1901, and have quite borne out the opinion we had formed. As will be explained later on, we are at present doubling the plant, though three years' experience has suggested certain improvements in the size of the oven.

In order to show the difference between the Hüssener oven and others in general use, both in this country and Germany, I have reproduced sections of the following ovens on Plate XIII. :—

Fig. 1. Semet-Solvay oven.

Fig. 2. Brunck.

Fig. 3. Collin.

Fig. 4. Simon-Carvés.

Fig. 5. Otto.

1904.—i

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The arrows show the direction in which the heating gas passes through the various flues, and can be compared with the similar section illustrated on Plate XIV., Figs. 1 and 2, of the Hüssener oven. Section AA, Plate XV., is through the flues at the ram side; BB, the middle of the oven; and CC at the coke bench end. It will be noticed that between each oven there is a solid brick wall, which carries not only the top arch of the oven but also all the superstructure, leaving little or nothing to be carried by the side walls of the coking chamber. These walls can, consequently, be made very much thinner than is usual in other forms of ovens, and so allow the heat to pass more readily through them. There is, therefore, less consumption of gas for heating the coking chamber.

The horizontal divisions of the flues are built into this wall, and the bricks are dovetailed into the vertical ones, which in their turn are tongued and grooved. This arrangement permits any single oven to be laid off for repairs without interfering with the working of its neighbours, and also allows the vertical walls of the oven to be removed and rebuilt without disturbing the top of the oven in any way.

At the ram engine side the oven is fitted with ordinary fire doors, in order to get up heat on starting, and on each side of the charging-holes there are two loose bricks (marked *a* and *b* in the section BB); by taking these out gas from the ovens is allowed to pass into the flues without going through the washing apparatus. This arrangement also permits the ovens to be used for the manufacture of coke alone, without the by-products. As soon as the oven is in work, and when making by-products, these holes are permanently bricked up. The oven has three charging-doors and one gas off-take.

In regular working, the gas coming back from the various washers, &c., enters on the ram side underneath the floor of the oven into two parallel flues, and between which is a solid brick wall. Each of these flues is connected with the upper flues of the oven, on the same side. The great advantage of this is, that the heat can be the more easily regulated on each side of the oven. The gas, having passed through the bottom flues, rises up to the top of the oven, receiving on its upward course a second, and on turning into the top flue (section C) a third supply of fresh gas.

After passing back in the upper flue, the gas falls to the second one (section A), being enlivened by a fourth supply of gas, and then passes through the third flue, enlivened as before, down into the fourth (here it has been found unnecessary to admit any more gas), and so into the waste flue leading to the boilers and chimney.

It will be seen that the flues are really in two separate systems, each heating one half of the oven, both bottom and side. All the gas is forced to pass through every part of the flue, and cannot take a short cut to the chimney. As it is enlivened in so many places, the heating of the coking chamber is very regular, and is entirely under the control of the burner. A large proportion of the air necessary to burn all the gas is admitted in the bottom flues; any further supply can easily be regulated by means of the sight-holes, which are fixed close to the inlets. About 70 per cent. of the gas from the coking process is used in heating the ovens, and, having done this, passes under the boilers at a temperature of about 1500° Fahr., raising sufficient steam, not only to work the exhausters for the ovens themselves, but also for the by-product plant, and then leaves about two-thirds of the steam available for other purposes.

At Clarence we have sufficient hot gas coming from the oven flues to work nine boilers about 30 feet long by 8 feet in diameter. The other 30 per cent. of the gas is available as live gas for other purposes. One ton of coal treated in the ovens gives sufficient hot gas to evaporate about 24 cwts. of water.

Diagrams (Plate XVI., Figs. 1, 2, and 3), taken by means of the Le Chatelier electric pyrometer, and photographed, are given, showing the temperatures of the gases in the side flues of the ovens—the flue going to the boilers (Plate XVI., Fig. 1), and so to the chimney (Fig. 2), and also of the mass of coke during the process of manufacture taken in different positions (Figs. 3 and 4). The diagram (Fig. 5), where the couple was lying on the top of the coke, shows the fall in temperature as the moisture in the coal is given off.

The average of fifteen analyses of gas coming from the ovens, after passing the condensers and ammonia scrubbers, is:—

CO <sub>2</sub>	.	.	.	.	.	.	1.2 per cent. by volume.
CO	.	.	.	.	.	.	.6 " "
CH <sub>4</sub>	.	.	.	.	.	.	31.5 " "
C <sub>2</sub> H <sub>4</sub>	.	.	.	.	.	.	1.5 " "
H	.	.	.	.	.	.	55.5 " "
O	.	.	.	.	.	.	0.1 " "
N	.	.	.	.	.	.	6.6 " "
<hr/>							100.0 per cent. by volume.

Its calorific power expressed in British thermal units is 571.2 per cubic foot at 0° C. and 760 mm. Calories 143.9 per cubic foot at 0° C. and 760 mm., or 5079.7 per cubic metre at 0° C. and 760 mm.

The gas, after it leaves the heating chambers of the ovens, consists of:—

CO <sub>2</sub>	.	.	.	.	.	7.9 per cent.	
O	.	.	.	.	.	3.5 " "	=16.6 of air.
N	.	.	.	.	.	88.6 " "	
<hr/>							100.00

The oven which is illustrated in the Plates is not the one which we have now working at Clarence, but represents what we are at present building, which is, we consider, a great improvement. The principal difference is in the height, which is 2.100 metres to the crown of the arch, as against 1.775 metres in the present ovens. Both are 10 metres long, 0.475 metres wide at the narrow, 0.535 metres at the broad end, and 0.505 metres in the centre. This new oven, which we intend to charge by means of a compressor, will, we think, make about 16 per cent. more coke.

Having now explained the construction of the Hüssener oven, and the reasons which induced us to put it down at the Clarence Works, I will give you the results of the working, not only of the oven itself, but also of a blast-furnace using very little coke other than that made at Clarence in the Hüssener ovens.

During the year 1903 we have treated about 105,000 tons of coal as received from the collieries, and the yield has been:—

	Per Cent.
Of good blast-furnace coke . . . . .	65.50
Breeze . . . . .	2.19
	<hr/> 67.69

on the coal so received.

On the washed coal absolutely sent to the ovens, and considered as dry coal (*i.e.* less 10.60 per cent. of water), the yield has been :—

	Per Cent.
Good blast-furnace coke . . . . .	72.04
Breeze . . . . .	2.41
	<hr/> 74.45

The hardness of the coke is shown by the very small proportion of breeze, viz. :—

	Per Cent.
Coke . . . . .	96.77
Breeze . . . . .	3.23
	<hr/> 100.00

In order to test the hardness of different kinds of coke, we have in the laboratory a cast-iron drum, revolving at the rate of 1000 revolutions per hour; 28 lbs. of dry coke are put in this, and the drum is revolved for one hour. The average weight of powder passing through an  $\frac{1}{8}$ -inch sieve in the case of our own beehive coke is 7 per cent., and with the Hüssener coke 5.9 per cent., proving that this form of retort oven makes the harder coke.

The average analysis of the coke has been :—

	Per Cent.
Moisture . . . . .	3.97
Ash . . . . .	8.18
Sulphur . . . . .	1.03
Volatile matter . . . . .	0.82
Fixed carbon . . . . .	86.00

The volatile matter in the coke drawn off by the mercurial pump consists :—

CO <sub>2</sub> . . . . .	0.24 per cent. of coke.
CO . . . . .	0.30 " "
CH <sub>4</sub> . . . . .	0.06 " "
H . . . . .	0.09 " "
N . . . . .	0.13 " "
Total . . . . .	<hr/> 0.82 per cent. of coke.

The results of passing  $\text{CO}_2$  over the coke was that—

From 1500 to 1549 the gas contained				1	per cent. of $\text{CO}$ .	
"	1550	"	1599	"	"	"
"	1600	"	1649	"	3.5	"
"	1650	"	1699	"	5.0	"
"	1700	"	1749	"	9.0	"
	Above 1750	"	"	"	15.0	"
		"	"	"	18.5	"

It will be seen that the coke made at Clarence is better than that made experimentally in Germany; in fact, it is as good as that made in our beehive ovens.

The production of each oven was 22.71 tons of coke per week, each charge consisting of 5.86 tons of dry coal, giving 4.36 tons of coke. The time required for coking is thirty-two hours, and, from this, each oven should have made 5.25 charges per week; in absolute work, the average was 5.21 charges.

It must be remembered that the coal contains  $10\frac{1}{2}$  per cent. of water as it goes into the ovens. The diagram, Fig. 4, shows that for ten hours the temperature in the centre of the mass of coal remains stationary at  $212^\circ \text{F}$ ., until this water is driven off.

We are only making, as by-products, tar and sulphate of ammonia—the benzol works having only just been completed.

				Cwts.
The yield of tar has been	.	.	.	1.06 per ton of coke.
" sulphate	.	.	.	0.33 " "

We also make pitch, but have only done so for a short time, working up a stock which had accumulated during eighteen months. It is therefore impossible to give the yield of this product.

There is one question which is always a very serious one in the retort ovens, and that is the repairs. I have taken out the cost over the last twelve months, after the ovens had been working three years:—

				Pence.
Wages	.	.	.	0.98 per ton of coke.
Stores	.	.	.	0.62 " "
				<hr/> 1.60 " "

which compares very favourably with other ovens.

After all is said, the final proof of the coke is its work in the blast-furnace, and, for this purpose, I will give the workings at Clarence for eighteen consecutive weeks, making iron entirely from Cleveland stone.

Seven furnaces, using practically all beehive coke, made an average of 780 tons of iron per week per furnace, using per ton of iron :—

Coke . . . . .	22.73 cwt.
Ore . . . . .	47.19 "
Limestone . . . . .	12.10 "

The burden of these furnaces per unit of coke was :—

Ore . . . . .	2.08 units.
Limestone . . . . .	0.53 "

Of these, five furnaces get the blast from a common main. Their work was :—

*Make per Week, 763 tons per Furnace.*

Coke used (beehive) . . . . .	22.71 cwt.
Ore used . . . . .	47.41 "
Limestone . . . . .	12.22 "

Burden per unit of coke :—

Ore . . . . .	2.09 units.
Limestone . . . . .	0.54 "

The other two furnaces have separate engines, but the blowing power is not quite powerful enough. Their work is :—

*Make per Week, 821 tons per Furnace.*

Coke used :—

Beehive . . . . .	21.92 cwt. per ton.
Hüssener . . . . .	0.83 "
Total . . . . .	22.75

Ore used :—

Cleveland calcined . . . . .	46.62 cwt.
Gellivare . . . . .	0.09 "
Total ore . . . . .	46.71 "
Limestone . . . . .	11.77 "

Burden per unit of coke :—

Ore . . . . .	2.05 units.
Limestone . . . . .	0.52 "

The furnace using practically only Hüssener coke was making a special iron, low in silicon and sulphur, which is sent direct to the open-hearth steel furnaces; this accounts for the large



quantity of limestone used per ton of iron. The blast is blown by a very powerful engine, capable of working against a pressure of 20 lbs. per square inch. During the same period the working of this furnace has been :—

*Make per Week, 1163 tons.*

Coke used per ton :—

Hüssener . . . . .	21.45 cwt.
Beehive . . . . .	1.43 "
Total . . . . .	<u>22.88</u>

Ore used :—

Cleveland calcined . . . . .	47.90 cwt.
Gellivare . . . . .	0.02 "
	<u>47.92</u> "
Limestone . . . . .	8.84 cwt.
Dolomite . . . . .	4.92 "
	<u>13.76</u> "

The burden per unit of coke was :—

Ore . . . . .	2.09 units.
Limestone . . . . .	0.60 "

In order to test further the working of the Hüssener coke, samples of the gas were taken over some days, when the consumption of coke was 22.44 cwt. per ton—the result being :—

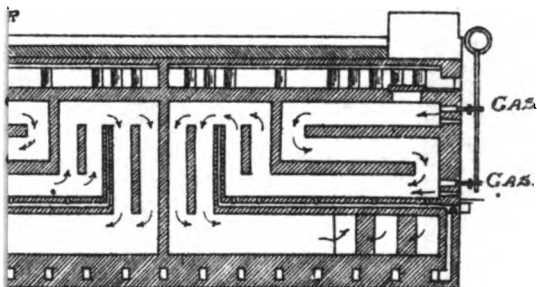
Carbon at the tuyeres, by calculation . .	16.28
" " analysis . .	<u>16.62</u>
Gain . . . . .	0.34, or 2.09 per cent.

The coke is now brought from the ovens in the furnace barrows, care being taken that it should never go into the furnace hot, and in this we find a very great advantage—the coke being in a much better condition.

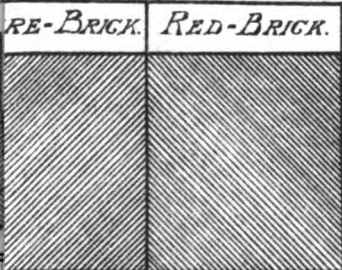
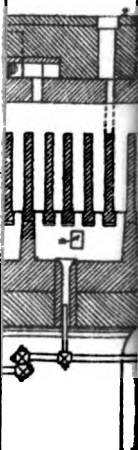
I feel I should not have done my duty to the gentlemen who have assisted me, not only in the preparation of this paper, but also in the experiments which led us to put down the Hüssener oven, if I did not express my thanks to Mr. Greville Jones, who is in charge of the Clarence furnaces, for the great attention he

FIG. 3.

— GOLLIN OVEN —

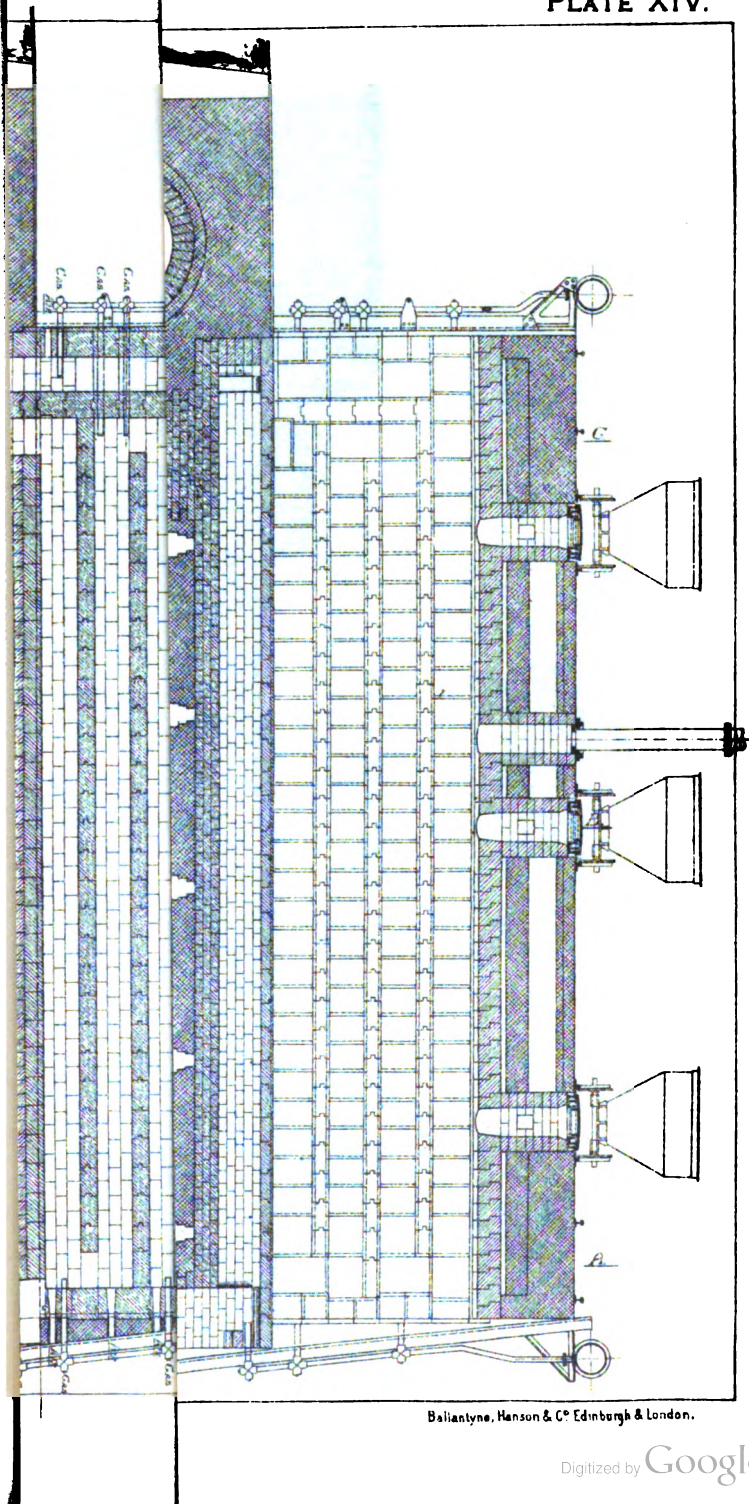


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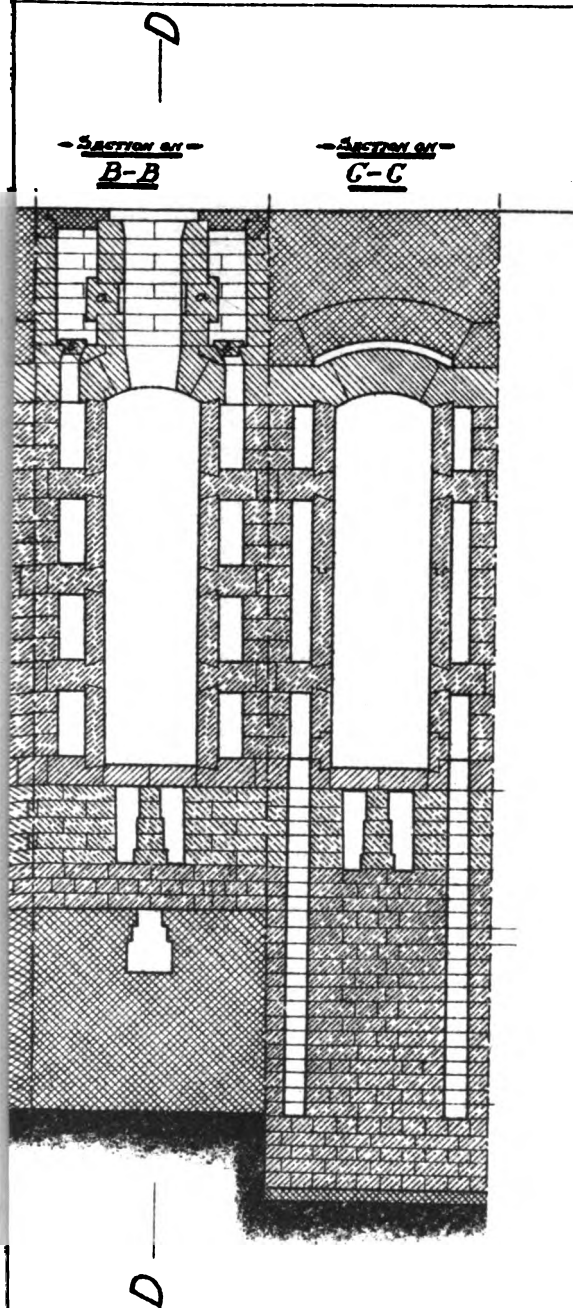


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Fig. 1.

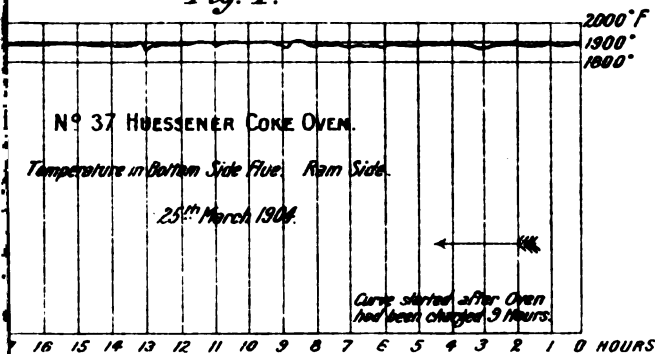


Fig. 2.

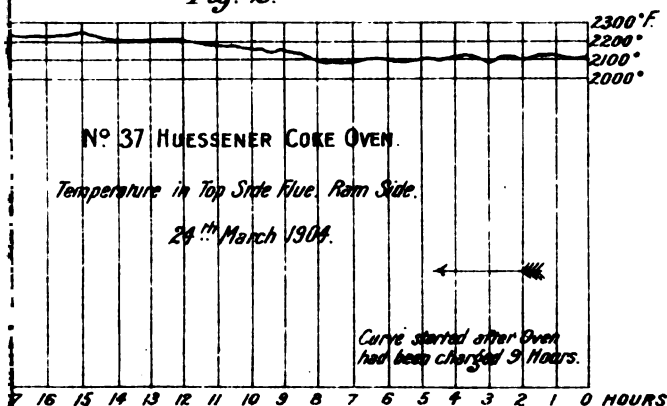
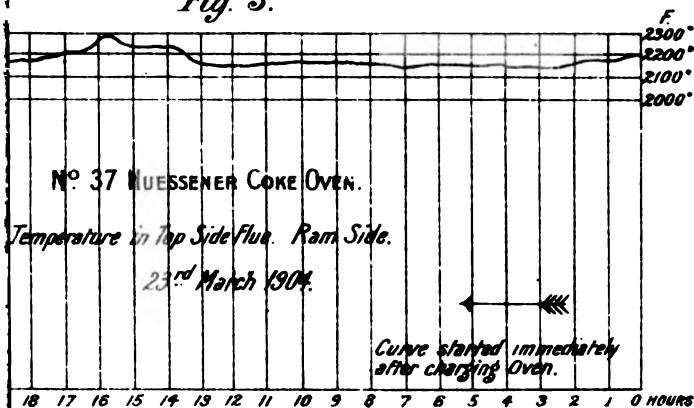
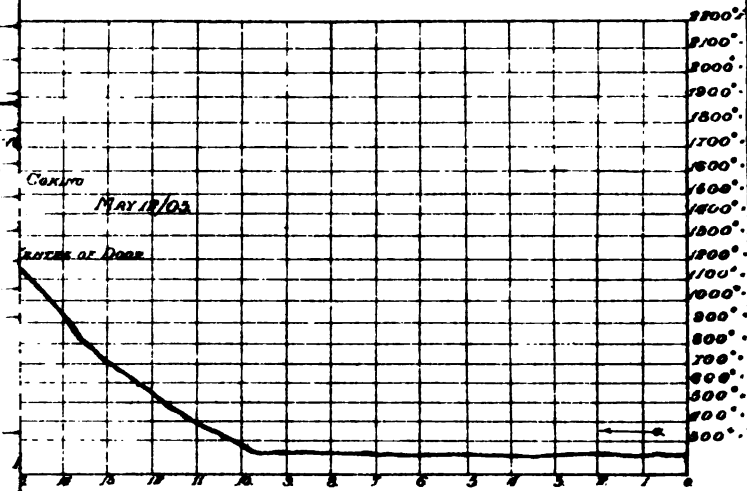


Fig. 3.









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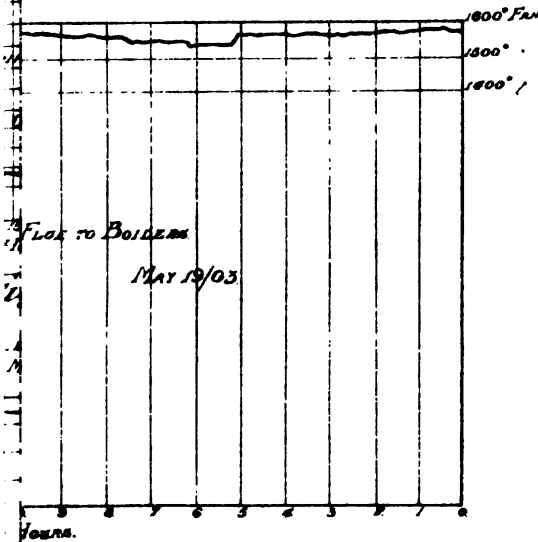


Fig. I.



gave to the workings of the different furnaces, and to Mr. Weldon Hanson for the care he exercised in the analyses.

At Clarence, we think we have solved the question of retort-oven coke, and are perfectly satisfied with the results we are getting, and this is due, to a very great extent, to the way in which we have been seconded by Dr. Roelofsen, the manager of the Clarence ovens.

*DISCUSSION.*

Mr. GEORGE AINSWORTH, Member of Council, said that the paper was as valuable and as full of information as, from past experience, they naturally expected in anything which emanated from Clarence. But there was one item which he should like to ask the author to give some further information upon, namely, what was the yield from that same washed coal in an ordinary beehive oven, of course assuming dry coal or the same quantity of moisture?

Mr. WILLIAM HAWDON (Middlesbrough) said Mr. Bell had given valuable information, and he was sure that the iron trade was very much indebted to him for giving the information which he had done in the paper. The retort oven question was a most important matter to coke makers and to iron makers. Millions of pounds were absolutely blown away at the present time into the air, which he regarded as an absolute national loss. If all coke were made in retort ovens, as it ought to be, that loss would be saved. He proposed to add in corroboration of Mr. Bell the work they had done at Newport. They happened there to have two furnaces working entirely on retort oven coke—made in the Otto oven. They were making iron precisely similar to that which Mr. Bell made for his firm, for steel making. It was made from Cleveland ironstone. Therefore all round they were on the same footing as they were at Clarence. That being so he proposed to put the Newport results beside those of Mr. Bell. They were wonderfully similar in results, the only difference being that they at Newport did somewhat better. He said that not from egotistical motives, but because any one reading Mr. Bell's paper would imagine that the Hüssener oven was the only oven in creation from which they could get those results. That was absolutely wrong. The Hüssener ovens, and ovens of a similar type with horizontal flues, were not nearly so good, and one did not get such good results all round as one did from the vertical flue ovens. The ovens they had at Newport were of the Otto-Hilgenstock type, and the difference between the two was that in the horizontal

flue ovens the gas was put in at one end of the oven, it travelled backwards and forwards in flues, whilst in the vertical type it simply rose up to the height of the oven. Therefore in the horizontal flue oven one got a travel of some 33 feet, and naturally the gas was very much cooler after travelling that distance than it was after a vertical rise of about 4 or 5 feet. That was a most important matter in the working of coke ovens, firstly, because one wanted to get the temperature from end to end of the oven precisely the same, in order to get good coke, and secondly, because of the varied expansion which one got in an oven where the gas was cooler at one part than it was in another. That was a most important matter. With regard to the drawing which Mr. Bell had given of the Otto oven, that was one which he had not seen before. He thought it must be one of the first brought out. They now put in ten burners instead of the six or seven which were shown on the drawing, which was a most important matter, because one got a much more equable temperature throughout. Referring to Mr. Bell's paper, he found that in the Hüssener oven they took 33 hours in coking. They did better in the Otto ovens—one battery took  $28\frac{1}{2}$  hours and the other 30 hours. They used dry coal, whereas Mr. Bell used wet coal, which made some difference in the time of coking. On the other hand, the latter's oven was an inch narrower than theirs, which enabled them to coke much more quickly. On page 191 Mr. Bell gave the volatile matter in the coke as 2·47, and he pointed out that they did not get as good work as they did with the other, or beehive coke. He would like to point out that he had 19·9 per cent. of fixed carbon in the retort coke, as against 20 per cent. in the Brancepeth, and therefore, although they used more coke so-called, they did better with the fixed carbon of the retort oven coke, which after all was the test of the coke. The question of volatile matter was a most important one. They found that when one did not drive off the volatile matter in coking one got scaffolding in the blast-furnace, and so on; but with the volatile matter driven off, one got as good or better results with the retort oven than one did with the beehive oven. He thought that the idea of coke made in a retort oven not being so good as that made in the beehive ought to be knocked on the head. It was pointed out by Mr. Bell that the

gas was absolutely under the control of the worker. He wished to point out that in those ovens with horizontal flues it was absolutely impossible to have the control over the gas which one had with the vertical flue. However, he did not wish to say much about the particular type of oven. What he wished to get at was the work they had done with the retort oven coke, which he thought would be of more interest to the Institute. Another important matter, however, with the retort ovens, particularly for people who had steel works, was the amount of gas that one had to spare after heating up the ovens. They had put in a meter, and found that at Newport with the Otto oven they had 33 per cent. of gas to spare after heating up the ovens themselves, and from the gas passing through the ovens, which passed away to the boilers at a temperature of 2141° Fahr., they evaporated 25·3 cwts. of water, as against 24 cwts. at Clarence. Besides that there was the chimney heat, which appeared to be included in the Clarence result, and which if taken into account would bring it up to somewhere about 33·7 cwts. of water, which was a very important thing in connection with steel works or collieries. On page 197 Mr. Bell gave the analysis of the coke, the percentage yield of good blast-furnace coke from the Hüssener oven at 72·04 per cent., and the breeze at 2·41 per cent. with dry coal; at Newport they got 77·49 and 2·35 per cent. That was an increase in the yield of 5·4 per cent. of coke on the dry coal. Their analysis showed water 2 per cent., as against 3·97 per cent., and fixed carbon 87·23, as against 86. Therefore after deducting 1·96 per cent. difference of water they got 7·41 per cent. better yield of coke than they did out of the Hüssener oven. On page 198, comparing the repairs of the oven, Mr. Bell gave the wages at 0·98d., and stores 0·62d., making a total of 1·60d.; their repairs at Newport had worked out absolutely on the brickwork at 0·28d. per ton, and adding stores and so on, a total cost of 0·9d. per ton of coke. He thought these figures might be of interest to the Institute. Comparing the results in the blast-furnace, they had in No. 7 furnace last year made 1089 tons of iron per week, using 22·6 cwts. of coke, of which only half a hundredweight was beehive coke, and in No. 8 they made 1216 tons of iron per week, using 22·7 cwts. of coke, using exactly the same

amount of ironstone as Mr. Bell, 47·9. Their biggest makes had been 1364 and 1365 tons in two consecutive weeks. He mentioned that to show that the use of retort oven coke had absolutely passed from the experimental stage. He thought Mr. Bell on reflection would admit that one could make good coke from other than the Hüssener oven. They had shown they had got 7·4 per cent. more coke from the coal; that they used rather less coke in making the iron, and adding that to the extra yield of coke from the oven, one got it running out to 3·2 cwts. of coal per ton of pig iron made as the difference between theirs and the Clarence oven. He would like to congratulate the author on putting that paper before the Institute, as he considered it was a very important matter to the iron trade.

Mr. JAMES RILEY, Vice-President, said that, like everything else which emanated from Clarence, the work recorded in the paper was thoroughly done. The paper was a very interesting one, and contained information which he thought had not been put before the members previously. But he rather demurred to the dogmatic conclusion that at last the question was solved of retort *v.* beehive ovens, and that it was solved by the adoption of the Hüssener oven. He had to do with forty ovens of the Otto-Hilgenstock type. All the information and the results they had obtained hitherto in operating them went to confirm the results given by Mr. Hawdon. But their experience was still too short for him to put the figures before them. As he had said, he only rose in order that judgment should be suspended for some little further time, until further figures could be put before the Institute.

Mr. FRANCIS A. E. SAMUELSON (Thirsk) said that in the year 1896, after they had already had some experience with retort ovens, he was sent by his firm to Germany to try and find out what was the best system. He met the late Mr. Albert Hüssener, whom he had met before in 1885, and he thought there could be no doubt that there was no greater expert in coke ovens. Anything that Mr. Hüssener did in the way of devising coke ovens would be undoubtedly as good as it could be made. He had not a word to say against the



Hüssener oven. Mr. Bell's figures, which came very near to their own, were evidently about as good as could be obtained. At the time of Mr. Samuelson's visit in 1896, Mr. Hüssener had shown no inclination to build ovens for other firms; he believed at that time he had only built for himself. The question of adopting or not adopting the Hüssener oven never came under their consideration. But everything that he saw led him to the conclusion that there was only one better coke oven to be found anywhere than the Hüssener, and that was the Otto-Hilgenstock. All he saw at the time was an experimental block of about 12 ovens; but he was convinced that the system of firing underneath and doing away with regenerators was right. That was the only difference between the Otto-Hilgenstock and the Otto-Hoffman oven. There was, he believed, only one plant of Otto-Hilgenstock ovens actually at work at that time. Mr. Hawdon went and saw that plant, and was satisfied with its actual working, as Mr. Samuelson had been with the experimental oven which he had seen. They then put down 50 Otto-Hilgenstock ovens at Newport, and at the time they thought they had no room to put down any more. But they were so satisfied with those ovens that about a year later they made the discovery that they had more room than they had thought, and they put down 80 more, making a total of 130. If they had had still more room, they would have put down more ovens still. They would put down more now if they could, but he thought they had really got to the end of their available space; they could not put down any more. He fully confirmed everything which Mr. Hawdon had said about the entire success of those ovens, and he did not think there was anything better to be found anywhere. He would like to refer once more to Mr. Hüssener, whom he met on a good many occasions, and whom he remembered as a most able and courteous gentleman, who had been very kind to him, and who had assisted him very much in his inquiries.

Dr. WALTHER HIBY (London), as a representative of the Otto-Hilgenstock coke ovens, asked to be allowed to add a few words upon Mr. Bell's paper, and the conclusions which had been drawn from some of the points which he had mentioned,

which seemed to him to require further discussion. It was stated by Mr. Bell that the quantity of water in the coal was the average 10·60 per cent., and considered that an advantage on even when not compressing the coal. He was quite of the same opinion, but he preferred to explain that the moist coal formed a more compact layer, and in this way the moisture to a certain extent compressed the coal. He could not admit that the slowness of the process brought about by the moisture of the coal caused the coke to be harder and denser. Mr. Hawdon had alluded to the interesting schedule by Mr. Bell which showed that a slightly larger quantity of retort coke was indeed used per ton of pig iron; but if they noticed the figures given for fixed carbon per ton of pig iron made, it would be seen that no greater quantity of fixed carbon in the retort coke was required than in the beehive coke. He concluded therefrom that the fixed carbon in the retort coke was not less effective than the carbon in the beehive coke. It seemed to him that the truth of the matter was that more retort coke was required, because the coke contained more volatile matter.\* He agreed that it was important to take notice of the volatile matter left in the coke, but he should say that a highly heated retort oven was quite able to make as good a coke in that respect as the beehive oven. He would further add that a high heat during the coking process was of greater importance than what Mr. Bell called the soaking of the coke after the completion of the coking process. Mr. Riley had alluded to a batch of 40 ovens of the Otto type at a colliery near Leeds. They coked the same coal partly in Otto ovens and partly in beehive ovens. They found, as a matter of fact, that the quantity of volatile matter left in the Otto coke (from the same coal) was quite as small, if not smaller, than that left in the beehive coke. The better results obtained as compared with those obtained with the Clarence ovens seemed to him to be brought about by the higher temperature in the Otto coke ovens. The temperature in the heating flues of those ovens was far higher than that given in the diagrams attached to Mr. Bell's paper. Let them take, for instance, the table on

\* He should say that the retort coke referred to was not properly coked; to use the Durham term, it was drawn before it was off.

page 190, which gave the temperature on the top of the coal. They found by comparison that the heat during the coking process was on an average more than 200° Fahr. higher in the Otto oven than that shown in Mr. Bell's diagram. As the Otto ovens were heated from below, and the lower part of the oven was heated even more intensely than the top part, the heat in the whole of the coking chamber might be taken to be far higher than that of the ovens at Clarence. That difference in temperature was in his opinion clearly proved by the shorter coking time of the Otto oven. Such oven, if of the same dimensions as those at Port Clarence, would coke in about 26 hours. He might also refer in that regard to the results of tests given in a paper read two years ago before that Institute. There was also another point which seemed to him to show a better regulation of heat in the Otto oven, and that was the composition of the gas leaving the ovens. Mr. Bell stated that it had in it  $3\frac{1}{2}$  per cent. of oxygen at Clarence, equal to a surplus of 16 per cent. of air. He would scarcely consider that the combustion to be aimed at. There was no doubt always either oxygen or carbon-monoxide found in the waste gases, but they had no difficulty in regulating the heat of the oven in such a way that the content of oxygen or CO did not exceed 1 per cent. Referring again to the diagrams in Mr. Bell's paper, it was somewhat striking that the temperature in the main flues to the boiler was given as low as 1600° Fahr., while in the bottom side flue the temperature was shown as being 1900° Fahr. He wondered if the greater part of the difference of heat was lost by radiation into the foundation of the oven. He was sorry that the diagrams did not show the temperature in the sole flue of the oven. In the Otto ovens the temperature in the main flue leading the gas to the boilers was above 2000° Fahr.—Mr. Hawdon had given it as 2100° Fahr. at Newport works—which was another proof to him that the heating of this coking system was the more effective one. They might also conclude that the steam-raising capacity of the Otto oven was greater than that of the ovens at Clarence. One gentleman had said that the section of the Otto oven did not represent the oven as actually built—in fact it was a copy of

the illustration which was attached to the patent specification of the year 1896. Mr. Bell gave them the illustration of a bigger oven than the one in use at present, and considered it a great improvement. He, however, had some doubt if Mr. Bell would find that the regulation of the heat in that bigger size oven would be as easy as in the present one.

Mr. ENOCH JAMES (Cardiff) said it had fallen to his lot to see the ovens at work at Clarence on many occasions during the last few years, and by the kind permission of Messrs. Bell Brothers he had been permitted to see not only the coke but the ovens in which the coke was made, and also the blast-furnace in which the coke was used. Thanks to the foresight of their Past-President, Mr. Windsor Richards, the retort oven was not an unknown institution in South Wales, and some of them had been brought up on retort oven coke—so-called coke. He represented a class which was not often allowed the opportunity of defending themselves, namely, the blast-furnace managers, who were accused of having an invincible prejudice against retort ovens. He did not know why any blast-furnace manager should have any prejudice against anything which was good for his blast-furnace. He thought that the inventors of coke ovens would have been well advised if they had listened more to the arguments and the complaints of the people who had to use their coke, and they would have found a remedy in a much shorter time than they had done. With regard to beehive oven coke he had nothing but sweet recollections of it. It was his lot to use the choicest Durham brands for some years, but when he went back to South Wales and had to take the control of some hundreds of those retort ovens, he found he did no better than his neighbours, for the defect was in the oven and not in the management. Possibly he spared his blast-furnaces to some extent by being more economical on the water outside, and also by returning the stewed coal which had not been converted into coke into the ovens in order to give them another opportunity. But the fault was in the oven, and it had taken them many years to improve those defects, because they did not listen to the people who had to use the coke. He was glad to notice that the various

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inventors of coke ovens were now coming out, and he was sure it would be much to the amusement of blast-furnace managers when they saw those people settle their differences. He was not representing any particular class of oven, but he was delighted to think that there was a prospect of some amelioration of the conditions of the blast-furnace manager. The coke which he found at Clarence he must say had much less black ends and much less coke dust than from any other coke banks that he had examined, and he had examined a good few in his career. The coke should be made outside the blast-furnace and not in the blast-furnace. Coke oven people had made a big reputation at the expense of the character of the blast-furnace, and he was afraid he must say also at the expense of some of the characters of the blast-furnace managers. One thing with regard to coke which struck him very forcibly was that the Middlesbrough district was beginning to copy what was good in South Wales. The location of the oven was rather an important matter, and when one saw that three or four of the most progressive ironmasters in Middlesbrough were no longer putting the ovens at the colliery but at the blast-furnace there was some reason for it. They did not pay carriage on 30 cwt. of coal as against 20 cwt. of coke unless there was some advantage in it, and they did not take the trouble of taking the coke from the bank in the barrows to the furnace instead of pitching it into a truck and letting it drop until it got into dust before it reached the furnaces, without some object. They went to the expense of 1s. a ton by making it at the furnaces and not at the colliery. He thought the work done at Clarence was highly creditable. 1300 tons from Cleveland stone must be recognised as a very good performance. But he was rather surprised with one remark in the author's paper, where he said that he was perfectly satisfied with his results. He was afraid that that satisfaction would not be of very long duration, and one fine morning Mr. Bell would find that one of his competitors had made 1500 tons, and then his peace of mind would be disturbed. The question had also a national aspect. It was about time that the British ironmaster should have some return from his continental colleagues, and it was very satisfactory for him to find that they were now getting from France

and Germany some return for all that the British ironmaster had taught them. He was a great admirer of some things done in America, and to his mind one of the biggest things that had been done was to capture the British press. They had captured it almost completely, and they were told constantly that if one wanted to see something well done they should go to America—that nobody did anything well except Americans. He thought that in that matter of coke ovens either they did not know a good thing when they saw it, or, having seen it, they were happy without it. They took a back seat compared with British ironmasters with regard to the adoption of by-product coke. If there were millions in it, as Mr. Hawdon had said—and there was no doubt there was—he believed that most of them would say that the British ironmasters were very much in need of some portion of those millions. There was a very hopeful prospect for the iron industry when they got the best results that could be obtained from what nature had so bountifully endowed them.

MR. TOM WESTGARTH (Middlesbrough) said that mention had been made of using surplus gas from coke ovens. He thought it would be interesting and perhaps useful to the members to know that his firm had to a certain extent accomplished that purpose. They had supplied Mr. Riley with two gas engines of 250 h.p. each for driving dynamos, which had been working with gas from his ovens now for some weeks with perfectly satisfactory results. They had not been working long enough to say that all the difficulties had been overcome, but long enough to assure them that the troubles were not likely to be very great. They had not had anything like the difficulty which they anticipated in cleansing the gases of their impurities, and the difficulty in using the gas had been very much less than they anticipated. He thought it was proper that he should also remind the members—it was also very interesting—that the first application on anything like a large commercial scale of the use of coke oven gas in gas engines was due to the enterprise of their Vice-President, Mr. Riley, who, together with Mr. Thwaites, were perhaps the pioneers in using blast-furnace gas in connection with engines in this country.

Dr. RIDEAL (London) said he rose to draw attention to one point which had not been alluded to in the discussion. He had the pleasure of meeting Mr. Lowthian Bell some weeks ago, and had a long conversation on the subject of the paper with him. He saw in the paper that the author repeated what he had told him then, that he had solved that particular problem. Other speakers had criticised the oven in relation to the Otto-Hilgenstock oven with regard to the coke and the volatile matter in the coke, which seemed to be the two factors which determined its value from the blast-furnace point of view. But in the paper Mr. Lowthian Bell admitted that the residuals had not yet been examined at all in detail at the Clarence Works, and the benzole plant, for example, had only just been erected. In dealing with that particular problem of the efficiency of the coke oven, one could not say that the problem had been solved until the quantity and the commercial value of the residuals had been taken into account *pari passu* with the value of the coke for blast-furnace work. From time to time there must arise conditions in which the different residuals would have values which would not be their intrinsic values, but would depend on the interchange of trade and the development of particular industries. He himself at the present time was particularly interested in the disinfectant value of the higher fractions of the tar, and he was assured that the various types of coke oven gave very different yields of these valuable products. So that for Mr. Bell on that occasion to come and say that he had solved the problem, he thought, with all due respect, required some modification, because until the problem of the working up of the residuals had been established one could not say that it was desirable to have a coke of a particular density, or a coke with a small amount of volatile matter, if the yield from the residuals produced by making the inferior coke for blast-furnace purposes was giving a much better return than in the other case.

Dr. DVORKOVITZ (London) said that he did not represent any coke oven or blast-furnace interests, but having studied the question of the best type of coke oven, and having had an opportunity of seeing most of the types in use in Germany, he

would like to make a few remarks on the subject. Stress had been laid by the author on the necessity of adding nearly 10 per cent. of water to the coke for the purpose, as he states, of producing a dense coke. This statement had been made some twenty years ago by Mr. Hüssener, and at the time considerable discussion took place as to whether this addition of water was a necessity or not; and Otto came to the conclusion that there was no necessity for adding water in order to get a dense coke. In fact, Mr. Bell, in the able record which he gave on Plate XVII., Figs. 3 and 4, showed that he kept his retort oven ten hours in the case of one retort and thirteen hours in the case of another retort at a temperature of 300–350° Fahr., and no doubt he kept it at that temperature in order to get rid of the excessive amount of water he had originally added. This explained why the time for coking was much longer at the Clarence Works than at such works where the Otto or Semet-Solvay ovens were used.

The next point was that the author made a statement in regard to the walls between the retorts being constructed much thinner than in other systems. This construction of the walls was quite an old form, and had been introduced in 1884 by Semet-Solvay, and, if it were an improvement, it was no doubt due to the latter gentleman, to whom it belonged.

There was another very important point, namely, the question of the quality of the by-products. After all, the construction of closed coke ovens, in comparison with beehive ovens, was very expensive, and the whole advantage of the one over the other lay in the fact that in retort ovens a certain amount of valuable by-products was recovered, which not only repaid the extra cost of construction but also left a good margin of profit. Without the recovery of by-products coking in retorts would be absolutely uneconomical. This very important point had been entirely omitted from Mr. Bell's paper, and it would be very interesting to have some figures concerning the value of the by-products received.

One of the speakers had made the remark that in the matter of the adaptation of new coke oven systems America had much to learn from this country. In answer to that it may be mentioned that in America they were making per annum at least 1,500,000 tons of coke in closed retorts and recovering the by-products.



Dr. WALTHER HIBY (London) said that one gentleman had said that in the Otto oven dry coal was coked, and that the coking time was lessened in consequence. At Tingley, in the wider Otto oven, the coking time was twenty-nine hours, and there the coal contained, as at Clarence, about 10 per cent. of moisture. Another speaker had alluded to the Americans and had said that they took a back seat; but that had been replied to by another speaker. He might add that their American friends, the United Coke and Gas Company, who owned the patent rights for the Otto oven in America, had of late years built twice or thrice as many Otto ovens in the States and Canada as all the coke oven builders together had built in England during the same period.

Mr. B. H. THWAITE (London) said that during his recent visit to the United States his friend Dr. Schniewind of New York had drawn his attention to a very considerable improvement in connection with the by-products of retort ovens. The great objection to the coke made in the retorts was that it was dirty. Mr. Edwin Moore had brought out an important improvement by which he obtained a semi-lustrous coke. He had a sort of secondary steel chamber, equal to the dimensions of the coke oven, and into it he forced the whole of the incandescent coke right away, and then closed the door and charged the secondary chamber immediately with water and as rapidly as possible in order to prevent the oxidation of the carbon, and the resultant dirty appearance. He produced by his rapid quenching method a beautiful lustrous coke from the by-product retort ovens, an improvement which he considered was of very great importance.

Mr. W. P. KIRKPATRICK (Brussels), speaking on behalf of Messrs. Solvay & Co. of Brussels, as manager of their coke-oven section, said that his attention had been specially attracted to the description of the oven given on page 194. He had the impression that he was reading a specification of the Semet-Solvay ovens when he came to the following words:—

“It will be noticed that between each oven there is a solid brick wall, which carries not only the top arch of the oven, but

also all the superstructure, leaving little or nothing to be carried by the side walls of the coking chamber. These walls can consequently be made very much thinner than is usual in other forms of ovens, and so allow the heat to pass more readily through them. There is, therefore, less consumption of gas for heating the coking chamber."

And again in the next paragraph:—

"This arrangement permits any single oven to be laid off for repairs without interfering with the working of its neighbours, and also allows the vertical walls of the oven to be removed and rebuilt without disturbing the top of the oven in any way."

These are exactly the special features of the Semet-Solvay ovens, which were patented in almost all countries in 1880-81, and about which many papers were read in technical meetings and pamphlets circulated.

If we look to Plate XIV., Fig. 1, of the paper just read, and compare the drawing of the Semet-Solvay oven to the design of the Hüssener oven on Plate XIII., Section EE, we find the same arrangement of horizontal flues in both types of oven. And if the transverse sections of the Semet-Solvay oven had been given, you would have seen that the two ovens are almost identical.

He invited the attention of the members to the drawing he had prepared, which showed, on the left, a transverse section of the Semet-Solvay oven as shown in the patents of 1880-81, and as they were constructed at Havré, in Belgium, shortly after, in the middle the same section of the Semet-Solvay oven as it is now constructed, and on the right the Hüssener oven at Clarence. They would see the striking similarity between the Hüssener and the Semet-Solvay oven. There were the same brick walls which carry the top arch of the oven and the superstructure, the same thinner walls of the coking chamber, and the same arrangement to permit any single oven to be laid off for repairs without interfering with the working of the neighbours.

About the time when the Semet-Solvay patents were taken, according to Wagner's "Chemical Technology," vol. 29, Mr. Hüssener introduced in Germany a modified form of the Carvès oven, and built a plant at Gelsenkirchen. As the members were aware, the flues of those ovens are built in the main walls, which carry the top arch and superstructure. All the books

which mention the Hüssener ovens describe them with that arrangement.

He noticed that Mr. Hüssener had given up the modified Carvès type. His firm felt very much flattered that Mr. Hüssener and the Clarence Iron Works had adopted an oven so similar to theirs, and also that Mr. C. Lowthian Bell should have declared it the oven that gave the best coke for use in the Clarence blast-furnaces.

In conclusion, he might say that all the good points which had been shown for the Hüssener oven could be safely extended to its parent, the Semet-Solvay oven, which had the same good features, and others in addition, and was capable of making, and indeed was making, coke at least equal in every respect to anything made in other ovens. Semet-Solvay ovens had met with great favour, and there were now 2295 ovens at work, or in course of erection, in different countries.

Mr. C. LOWTHIAN BELL in reply said that, with reference to Mr. Ainsworth's remarks as to the yield of coke in the beehive oven, with coal similar to what they were using at Clarence, he could not give any absolute figure, because at none of their collieries were they washing all the coal, but only a small part of it; the only place where they were washing the whole was at Clarence. He should think that the yield, in a beehive oven, of coal similar to what they were coking at Clarence, would be about 68 per cent. He agreed with Mr. Hawdon that the most important question of a coke oven was not that it should be hot, but that it should be heated regularly from the bottom up the sides and the top. Mr. Hawdon, in discussing the Hüssener oven, omitted to mention that in three or four places the gas in passing along the flues was enlivened, and that there are twelve places where fresh gas is admitted, so that, instead of having to travel some 33 feet and get cold before it had done its duty, the gas only had to travel 10 metres (that was along the oven once), and then it was enlivened before it started to travel the next 10 metres. The difference between the temperature in the diagrams at the bottom of the flue of the oven and the flue going to the boilers was easily accounted for. The temperature was taken at the boilers some distance away

from the ovens, so that the  $300^{\circ}$  was lost by radiation. It was very difficult, as Mr. Stead had said in the discussion on pyrometers, to get an accurate result as to the temperature in the flues of an oven, as there was a great danger of putting the wires of the Le Chatelier instrument into the gas flame, and not into the hot gas. In the bottom flue of the Hüssener oven this was certain to be the case; they tried to do it, but found it quite impossible. This appeared to have been so in Dr. Hiby's case, where, in the combustion flue, he showed a temperature of a little over  $2500^{\circ}$ , whereas, in the sole flue and the horizontal flue, the temperature was nearly  $2300^{\circ}$  and  $2150^{\circ}$  Fahr. respectively.

As regarded the temperature of the mass of coke at the completion of the operation, the mass in the centre in the Otto-Hilgenstock was a little over  $1600^{\circ}$  Fahr., and at the outside next the wall  $1740^{\circ}$ .

In the centre of the oven at Clarence, 4 feet 3 inches from the door, the temperature of the mass was about  $2150^{\circ}$ . From the diagrams of the Clarence oven, on Plate XVI., Nos. 2 and 3, it would be seen that the temperature in the flues was greater in the Otto-Hilgenstock than in the Hüssener oven; but the walls being thinner in the latter the heat could permeate more readily into the body of coke.

It was shown by Mr. Hawdon that repairs on the brickwork at Newport amounted to 0·9d. per ton of coke. The figure 1·61d., given as repairs at Clarence, included everything that was done at the coking plant, omitting, of course, any repairs that were done to the by-product department.

He would point out to Dr. Hiby that the coal at Clarence contained over 10 per cent. of moisture, and it required a considerable time to drive this off.

He would remind Dr. Dvorkovitz that the quantity of moisture in the coal was due to it all having passed the washing process. To make the coke dense would not require, in his opinion, anything like the quantity of water that the Clarence coal contained, viz., 10 per cent.

The coke maker had to consider also, not only the question of by-products, which it was perfectly true were recovered in the retort ovens, but another advantage was that there was very little of the coke burnt after manufacture as it was in the beehive.

In reply to Dr. Rideal, he could only say that he was dealing with the ovens as manufacturing coke for metallurgical purposes.

With regard to by-products, he did not think there was any finality to what could be done, not only in the benzol series, but also in other directions, as yet undiscovered.

He would only say to his colleagues in the iron trade, and blast-furnace managers, that, if any of them took sufficient interest in the Hüssener ovens to come to Clarence, they would be welcome, and shown the ovens and the coke. After all, seeing the coke was a great deal better than having anybody who was interested in the ovens saying that it was the best coke in the world. He did not say that the Hüssener oven was the only oven in the world, but what he did say was that it was the only oven which had satisfied him personally with the coke it made for Clarence.

Since the paper was read the furnace at Clarence for three weeks had averaged a make of 1286 tons.

Coke used per ton :—

Beehive . . . . .	1.44 cwt.
Hüssener . . . . .	20.17 "
Total . . . . .	<u>21.61</u> "

Ore used :—

Cleveland calcined . . . . .	43.53 cwt.
Other ores . . . . .	2.83 "
Total . . . . .	<u>46.36</u> "

Limestone . . . . .	8.27 cwt.
Dolomite . . . . .	4.00 "
Total . . . . .	<u>12.27</u> "

Scrap . . . . .	0.73 cwt. per ton.
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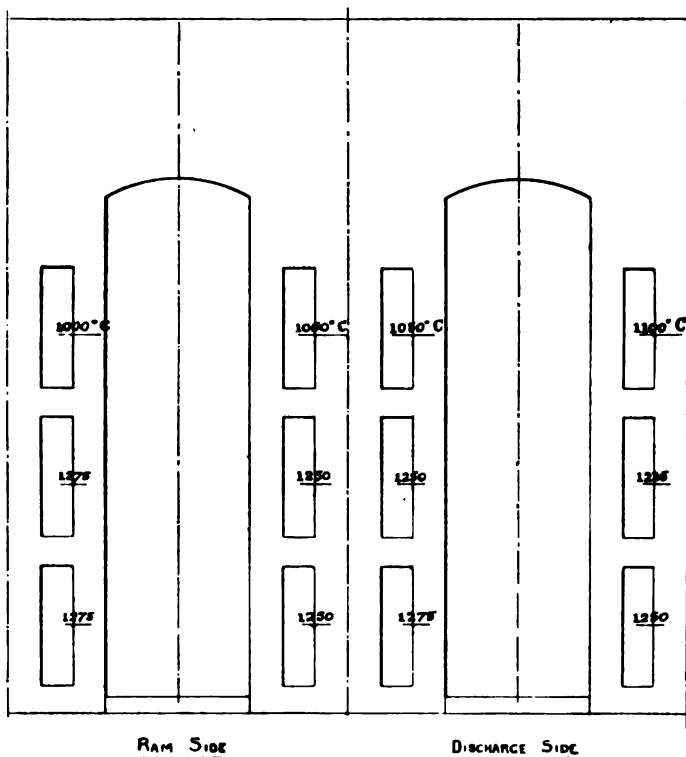
The burden per unit of coke was :—

Ore . . . . .	2.14 units.
Limestone . . . . .	0.57 "
Scrap . . . . .	0.03 "

Mr. WILLIAM WHITWELL, Past-President, moved a vote of thanks to the author for his most excellent and enlightening paper, the resolution being carried unanimously.

## CORRESPONDENCE.

Mr. J. H. DARBY (Brymbo) observed that in 1898 he had the honour of reading a paper on "Coking in By-product Ovens" before the Institute, and in that paper he tried to show that coke made in the Semet-Solvay oven was economical in the blast-



*Note.*—The top flues are purposely kept at a lower temperature than the rest of the flues

furnace. He gave an instance in his own knowledge where a furnace working on basic iron was using 20·93 cwts. of coke per ton of iron made, and he felt convinced then, as he did now, that retort coke, properly made, was as economical to use in the blast-furnace as "beehive" coke. It was gratifying to

him to see that in the exhaustive comparison made by Mr. Bell, between the duty of retort coke and "beehive" coke, he bore out the statement he (Mr. Darby) made six years ago, when prejudice was much deeper against the use of retort coke than at the present time.

The horizontal-flued oven did give a uniform heat from end to end, and the diagram given showed that there was nothing in Mr. Hawdon's contention that the vertical-flued oven gave a more even temperature than the horizontal flue.

The Hüssener oven was to all intents and purposes the same in construction as the original form of Semet-Solvay oven, including all the leading features :—

Supporting walls to carry weight of structure between each oven.

Gas and air admitted at various points.

Horizontal flues with thin slide tiles.

As described by Mr. Bell it was in fact the old Semet-Solvay renamed.

With regard to repairs to brickwork, he had had Semet-Solvay plants under his control where the repairs to brickwork for the first three years had been nil, but this was too short a period. He was sorry to say that no English-made lining brick he knew of (and he had tried many) would stand the intense and intermittent character of the heat, caused by the introduction of cold charges of fuel into the highly heated oven. He had had Belgian-made linings in constant use for eleven years, and they were still in good order.

The degree of heat in all ovens was limited by the refractory nature of the linings. Every oven built could be melted down if the amount of gas and air introduced into the flue was not properly regulated, and it was difficult to reconcile this with the statement made by Dr. Hiby attributing quicker and better working to the oven he represented, due to higher temperature. Under favourable conditions with regard to percentage of moisture in the fuel, and composition of the same, the Semet-Solvay ovens were the fastest working of all ovens, 16-inch coke being completely coked in 18 to 20 hours.

Mr. Bell laid great stress on the volatile matter in the coke, which no doubt was important. He (Mr. Darby) had had daily

tests made in a similar method to that described by Mr. Bell, and found a maximum of about 0·5 per cent., or an average of 0·3 per cent. volatile matter in coke when ready for the blast-furnace.

Mr. Bell was working in the right direction when he proposed to increase the size of the oven, and to adopt compression of the fuel before charging. Ovens holding up to 9 tons seemed to be about the limit as regards a convenient size.

In compression of the fuel before charging, Mr. Bell would find great improvements, viz.—

(1) 10 to 12 per cent. increase in production from a given plant.

(2) A better quality of coke.

(3) Little or no black ends.

(4) Breeze reduced so that 99 per cent. of the coke made can be used in the blast-furnace.

(5) Saving in labour.

(6) Prolonged life of ovens, due to the fact that the clearance necessary to introduce the charge prevents the damp cold fuel from pressing on the highly heated walls of the ovens.

He erected the first compressing plant introduced into the British Isles, and after four years' work he was able to testify to the great advantage derived from this method of charging coke ovens.

He quite agreed with Mr. Hawdon that there had been enough of talk and discussion regarding the value of retort coke in blast-furnaces compared with "beehive" coke. On the Continent, for years past, a man would be considered most imprudent to build anything but retort ovens, either with or without recovery of by-products.

Mr. J. INGLEBY (Manchester) remarked that Mr. Bell unwittingly did his firm an injustice in reproducing, as illustrating the Simon-Carvès oven, a block which illustrated almost the first development of by-product coke ovens. Since then they had much improved their oven, as the accompanying illustration would make clear. With regard to the results obtained in the thirty-five Simon-Carvès ovens at the Rotherham Main Collieries (John Brown & Co., Ltd.), they regularly made about 750 tons of coke



per week, which gave a yield of say,  $21\frac{1}{2}$  tons of coke per oven per week with coal of about 30 per cent. volatile matter, and the by-products showed per ton of coke :—

Tar . . . . .	1.12 cwts.
Sulphate of ammonia . . . . .	0.384 „

It was to be noted that the above figures were an average of twelve months' working, and further, that they recovered the crude benzol, of which they obtained about  $2\frac{1}{2}$  gallons per ton of coke.

Although their ovens burned somewhat longer than Mr. Bell mentioned, on the other hand they were much larger, taking about 10 tons of dry coal at a charge, so that the output in coke was as large, and he would submit that the greater charge of coal in the oven, and the longer coking, improved the quality and appearance of the coke. This could only be fully appreciated where the coke maker had (as in most cases where the ovens in question are built) to sell his coke in the open market and not use it himself in his own blast-furnaces, as in the case of Mr. Bell and Mr. Samuelson. This was an important consideration for people who were likely to build coke ovens in the near future, and who were not in the fortunate position of having their own blast-furnaces.

Mr. JOHN PARRY (Ebbw Vale) pointed out that thirty years ago he published a series of determinations (*Chemical News* and *Journal of the Iron and Steel Institute*) on the quantity and composition of the gases evolved from coke heated in vacuo. He had since found that of different veins of coal heated at a fixed temperature at ordinary pressure, some retained a sensible quality of volatile matter, requiring a further heat for complete elimination of gas. This he had always considered of great practical importance. He enclosed results not hitherto published, and which were embodied in the table given on the following page.

He might add that he had made a great number of assays of coke delivered to furnaces, and found the volatile matter varied from *nil* (in a very few instances) to as much as 6 per cent.

Average of twenty samples—

Volatile matter (in <i>dry</i> coke) . . . . .	1.15 per cent.
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*Yields of Coal, all heated at the same temperature.  
4 Grms. weighed.*

Coal.	Heated 2 hours. Coke.	Again 1 hour. Coke.	Loss first 2 hours.	Loss last hour.	Total Volatile Matter.	Coke.
No. 1 Coal	2·865	2·485	28·4	9·5	37·9	62·1
„ 2 „	2·534	2·477	36·7	1·4	38·1	61·9
„ 3 „	2·783	2·835	30·4	1·3 gain	29·1	70·9
„ 4 „	2·675	2·640	30·6	3·4	34·0	66·0
„ 5 „	2·940	2·870	26·5	1·8	28·3	71·7
„ 6 „	2·543	2·470	36·4	1·9	38·3	61·7
„ 7 „	2·613	2·517	34·7	2·4	37·1	62·9
„ 8 „	2·594	2·505	...	...	37·4	62·6
„ 9 „	2·533	2·456	36·7	1·9	38·6	61·4
„ 10 „	2·670	2·603	30·8	4·1	34·9	65·1
„ 11 „	2·667	2·627	33·4	1·1	34·3	65·7
„ 12 „	2·680	2·640	33·0	1·0	34·0	66·0
„ 13 „	2·810	2·761	29·8	1·2	31·0	69·0
„ 14 „	2·938	2·772	26·6	4·1	30·7	69·3
„ 15 „	2·589	2·493	35·3	2·4	37·7	62·3
„ 16 „	2·670	2·620	33·25	1·25	34·5	65·5
„ 17 „	2·650	2·574	33·75	1·90	35·65	64·35
„ 18 „	2·760	2·600	31·00	4·00	35·0	65·0
„ 19 „	2·760	2·660	31·00	2·50	33·5	66·5
„ 20 „	2·550	2·540	36·25	0·25	36·5	63·50
„ 21 „	2·790	2·770	30·25	0·5	30·75	69·25
„ 22 „	2·525	2·489	36·90	0·88	37·78	62·22
„ 23 „	2·680	2·654	33·0	0·65	33·65	66·35
„ 24 „	2·710	2·639	32·25	1·75	34·00	66·00
„ 25 „	2·580	2·515	35·5	1·60	37·1	62·9
„ 26 „	2·370	2·340	40·75	0·75	41·5	58·5
„ 27 „	2·420	2·388	39·50	0·80	40·3	59·7

## THE RANGE OF SOLIDIFICATION AND THE CRITICAL RANGES OF IRON-CARBON ALLOYS.

By H. C. H. CARPENTER, M.A., Ph.D., AND B. F. E. KEELING, B.A.,  
OF THE NATIONAL PHYSICAL LABORATORY.

THIS research had its origin in a suggestion made by Mr. R. A. Hadfield during his evidence given before the Committee appointed by the Treasury to consider the advisability of establishing a National Physical Laboratory in this country. Mr. Hadfield stated that a determination of the exact melting points of iron and iron-carbon alloys, "commencing, say, with pure iron, then steel with 0.1 carbon, the latter element gradually increasing till white iron, containing  $3\frac{1}{2}$ —4 per cent. carbon is arrived at," would be of great practical importance. The research has been extended to an investigation of all the evolutions of heat in the alloys from the beginning of solidification down to 500° C.

The results obtained by previous workers in this field have been embodied by Professor Bakhuis-Roozeboom in his well-known paper,\* and our work may be regarded as a test of the accuracy of his conclusions, which are summarised in the diagram opposite (Fig. 1), reproduced from his paper.

### MEASUREMENT OF TEMPERATURES.

The temperatures were measured by thermojunctions. Three of these have been used, one of them being a junction of platinum and platinum-rhodium (10 per cent. rhodium), and two being junctions of platinum and platinum-iridium (10 per cent. iridium). The diameter of the wires was about 0.5 mm. The two wires were autogenously soldered together in a small oxy-coal-gas blowpipe, and were annealed by glowing with an electric current. The free ends were hard soldered to copper leads. The junctions with the copper were kept at 0° C. by being placed in a box containing melting ice.

\* "*Le fer et l'acier au point de vue de la doctrine des Phases.*" *Zeitschrift für physikalische Chemie*, vol. xxiv. p. 437. See also *Journal of the Iron and Steel Institute*, 1900, No. II. p. 311.

All the thermojunctions have been compared directly with the standard thermojunction No. 2 of the National Physical Laboratory, which in its turn has been compared by Dr. J. A. Harker \* with the nitrogen thermometer up to about 1000° C.

Between 400° C. and 1000° C. the formula for this junction is—

$$E = -304 + 8.165t + 0.001663t^2$$

where  $E$  is the E.M.F. in microvolts and  $t$  is the temperature in

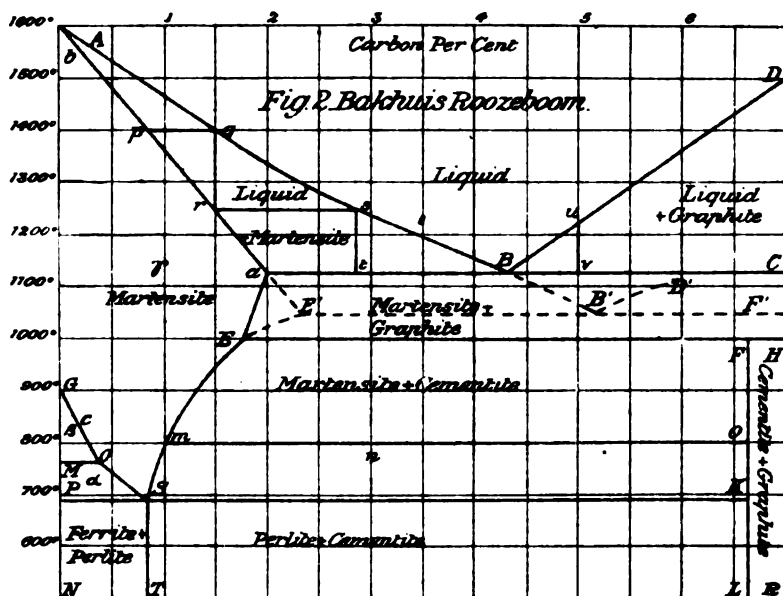


FIG. 1.

degrees centigrade. Using this formula, the formulæ for the thermojunctions used in this research were found to be—

Thermojunction  $M_4$  (Pt. - Pt. Rh.);  $E = -692 + 11.55t + 0.001245t^2$

Thermojunction  $M_5$  (Pt. - Pt. Ir.);  $E = -710 + 15.497t + 0.001193t^2$

Thermojunction  $M_8$  (Pt. - Pt. Ir.);  $E = -430 + 15.649t + 0.000779t^2$

The maximum deviation of the observations from values calculated from these curves was about half a degree.

For temperatures above 1000° C. the present state of ther-

\* *Phil. Trans. of the Royal Society, A. 1900, Proceedings, lxxiii. p. 217. 1904.—i.*

metric science does not enable us to obtain any direct reliable comparison with the gas thermometer, and the temperatures have been calculated on the assumption that the above equations hold good up to  $1500^{\circ}\text{C}$ . This at first sight seems a large assumption, but the following facts go to show that the extrapolation is not unreasonable. In the first place, the thermojunctions were compared with each other, and with the standard junction No. 2 up to about  $1300^{\circ}\text{C}$ ., and the relative values of the E.M.F. were found to be in accordance with the above equations. The junctions have very different equations, and if extrapolation is not justified, we should expect to get discrepancies at high temperatures. Further, it will be shown later that even near  $1500^{\circ}\text{C}$ . temperatures measured with thermojunctions  $M_4$ ,  $M_5$ , and  $M_6$  are in close accordance with each other. So that in any case we are justified in calling the temperatures above  $1000^{\circ}\text{C}$ . "temperatures on the thermojunction scale" without reference to the particular junction used, whilst below  $1000^{\circ}$  the temperatures are gas thermometer temperatures.

The junction subjected to the severest treatment was No.  $M_6$ , which was the one principally used for the solidifying points. As a safeguard, no undue parsimony in the use of platinum was observed; as soon as the wires showed any signs of deterioration (usually an increased brittleness), the faulty parts were removed and the junction re-soldered. The freezing point of pure silver was also determined with the junction from time to time, and finally a complete recalibration was made at the conclusion of the work. It was found that between  $1000^{\circ}$  and  $1300^{\circ}$  the temperature scale had risen about three degrees. All temperatures measured with this junction have been calculated on the mean of the two calibrations.

The potentiometer used for measuring the E.M.F. was a modified form of that described by Dr. Stansfield.\* The potentiometer box, A (Fig. 2), consists of two rows of coils,  $a, b, c$ , and  $d, e, f$ . Between  $a$  and  $b$ ,  $d$  and  $e$  are nine coils, each of 2 ohms, and between  $b$  and  $c$  and  $e$  and  $f$  are nine coils, each of 0.2 ohm. The lower row is broken at  $e$ . By means of plugs,  $p, q$ , connection can be made between the rows at any points desired. The thermojunction and accumulators were connected

\* *Phil. Magazine*, vol. xlv. pp. 59-82.

to this box as shown in the diagram, the accumulator circuit containing also the resistance boxes, B and C. When desired, the standard cells could be connected by a switch to the ends of B through the galvanometer, G. The standard cells used were two cadmium cells, each of 1.019 volts and negligible temperature coefficient. The resistance in B was 1019 ohms, and C was adjusted in the usual way until there was no galvanometer deflection. Consequently each 0.2 ohm between *p* and *q* corresponded to about 400 microvolts, i.e. about 23° C. The thermojunction E.M.F. were then measured by switching over the galvanometer into the thermojunction circuit and altering *p* and *q* till the nearest 400 microvolts were found. Subdivisions of 400 microvolts were determined by measuring the deflection of the galvanometer. This was a suspended coil galvanometer of about

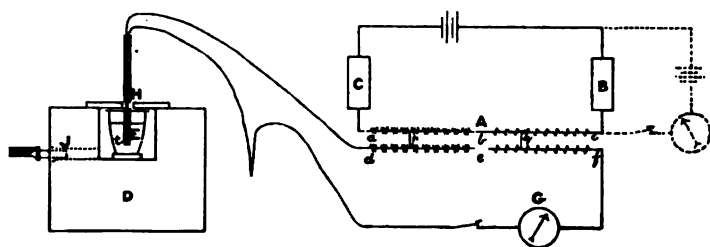


FIG. 2.

20 ohms resistance, and gave at a distance of about 150 centimetres a deflection of 100 divisions (each of 2 mm.) for each step of 0.2 ohm corresponding to 400 microvolts, or 1 mm. for 2 microvolts. One degree centigrade, equivalent to about 17 microvolts, was thus represented by 8 mm. on the galvanometer scale. No trouble was experienced by change in the galvanometer zero.

#### METHOD OF DETERMINING THE RANGE OF SOLIDIFICATION.

The alloys given in Tables I. and II. were prepared as follows, the materials being kindly presented by the instrumentality of Mr. R. A. Hadfield, the Hecla Steel Company, Sheffield.

Nos. 2 and 4 were made by melting Swedish charcoal iron.

Nos. 5 and 6 were made by melting samples of "Lilley iron."

Nos. 7-33 were made by melting suitable mixtures of "Lilley iron" with a Swedish high carbon iron.

No. 34 was made by melting the Swedish high carbon iron.

No. 35 was made by melting the Swedish high carbon iron with wood charcoal.

Nos. 36-38 were made by melting the Swedish high carbon iron with "carburite."

The analyses of these alloys and the materials from which they were made are given in Table I.

*Description of Furnace.*—The melting furnace used was a concentric jet crucible furnace capable of taking a No. 3 Morgan crucible. (A diagram of a vertical section of the furnace is shown in Fig. 2.) The gas flame under forced draught enters the furnace casing at J, spins round between the crucible, E, and the furnace wall, and issues from a hole in the firebrick cover at H. The thickness of the casing, D, is 5 inches in the narrowest part.

In all cases except that of alloy No. 2, where a magnesia-lined graphite crucible was used to avoid as far as possible the carburising action of the flame, the melts were made in salamander crucibles.

The method of procedure was as follows: From 3 to 4 lbs. of material were melted down, the crucible being closed by a lid. The time needed for this varied between thirty to thirty-five minutes for the high carbon irons, and about one and a half hours for the lowest carbon irons. If necessary, slag was then skimmed off and the mixture well stirred with a salamander rod. The heating was continued about ten minutes longer, the lid was then replaced by a fireclay cover with a  $\frac{1}{2}$ -inch hole drilled through the middle, and the flame turned out. The thermojunction, E, enclosed in a fireclay tube closed at the bottom, was inserted through the hole in the cover into the molten fluid, care being taken to place it as nearly as possible in the centre and at a distance of about  $\frac{1}{2}$  inch above the bottom of the liquid. By this means about 2 inches of the thermojunction wires were immersed. These were insulated from one another by a capillary porcelain tube through which one of them was threaded. The cold junctions were placed in an ice-box and the wires from here connected with the potentiometer. The arrangement at this

TABLE I.

*Tabulated Chemical Analyses of Alloys.*

## PERCENTAGES.

No. of Alloy.	Iron.	Total Carbon.	Graphite.	Silicon.	Sulphur.	Phosphorus.	Manganese.
1	...	0.01	...	...	...	0.04	trace
2	...	0.02	...	0.02	0.03	0.04	trace
3	...	0.05	...	...	...	...	...
4	...	0.12	...	...	...	...	...
5	...	0.16	...	0.06	0.01	...	...
6	...	0.17	...	...	...	...	...
7	...	0.24	...	...	...	...	...
8	...	0.38	...	0.06	0.01	0.03	trace
9	...	0.47	...	0.16	0.02	0.02	trace
10	...	0.53	...	...	...	...	...
11	...	0.61	...	...	...	...	...
12	...	0.80	...	...	...	...	...
13	...	0.80	...	...	...	...	...
14	...	0.81	...	...	...	...	...
15	...	0.93	...	...	...	...	...
16	...	1.31	...	...	...	...	...
17	...	1.51	...	...	...	0.02	trace
18	...	1.69	...	...	...	...	...
19	...	1.81	...	0.16	0.02	...	...
20	...	1.85	Nil	0.09	...	...	...
21	...	1.97	Nil	...	...	...	...
22	...	2.12	Nil	...	...	...	...
23	...	2.21	...	...	...	...	...
24	...	2.25	...	...	...	...	...
25	...	2.25	...	...	...	...	...
26	...	2.47	...	...	...	...	...
27	...	2.63	...	...	...	...	...
28	...	2.67	...	...	...	...	...
29	...	2.74	...	...	...	...	...
30	...	2.85	...	...	...	...	...
31	...	3.03	Nil	...	...	...	...
32	...	3.29	0.14	...	...	0.02	...
33	...	3.42	1.80	...	...	...	...
34	...	3.51	1.38	...	...	...	...
35	...	3.87	2.14	0.06	...	...	...
36	...	3.98	...	...	...	...	...
37	...	4.37	...	...	...	...	...
38	...	4.50	...	0.12	...	...	...
"Lilley Iron"	} ...	0.1	...	0.06	0.01	0.02	trace
High Carbon		4.3	...	0.18	0.02	0.02	trace
Iron Carbide		70	...	0.67	...	...	...



stage is shown in Photo 1 (Plate XIX.), the only omission being a screen placed between the furnace and the ice-box which had to be omitted for photographic purposes.

The cooling of the molten alloy was followed by taking simultaneous observations of temperature and time. By plotting the former as abscissae and the latter as ordinates curves are obtained, three types of which are illustrated on Fig. 3, L, M, and N.

Fig. 3, L, which is the solidification curve of No. 6 alloy, is typical of low carbon alloys of iron. It will be seen that just

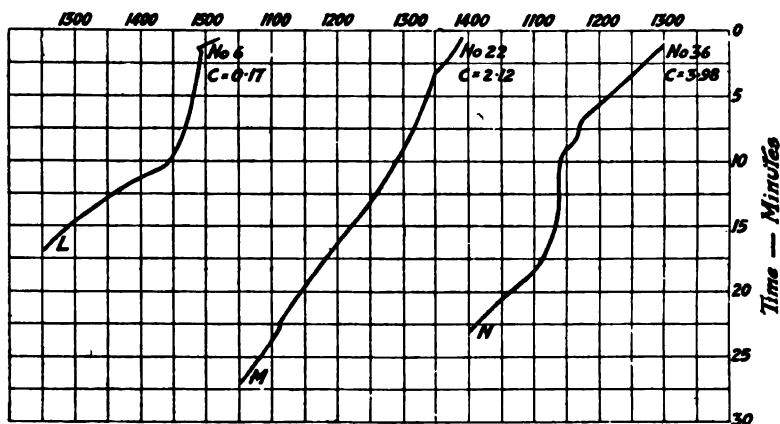


Fig. 3.

above the point at which solidification begins the alloy is cooling at the rate of about  $20^{\circ}\text{C}$ . in fifty-five seconds. A slight recalcence takes place at the moment of solidification in consequence of super cooling. The temperature then falls gradually, about five minutes being taken for the next  $20^{\circ}\text{C}$ . The curve, hitherto concave upwards, becomes a straight line as soon as solidification is finished at about  $1450^{\circ}$ , and for the next three minutes the temperature falls about  $20^{\circ}\text{C}$ . in each succeeding forty seconds. After this it becomes convex as the temperature of the alloy gradually regains that of the furnace.

Fig. 3, M, the solidification curve of No. 22 alloy, is typical of alloys whose carbon percentage is greater than 2.1. The end of solidification is marked by a recalcence caused by the solidification of the eutectic, containing 4.3 per cent. carbon. The

range of solidification of this particular alloy is  $250^{\circ}\text{C}$ .—the widest of the whole series.

Fig. 3, N, the solidification curve of No. 36 alloy, is typical of alloys whose composition approaches that of the eutectic, the range of solidification being in this case only  $33^{\circ}$ .

The results of the observations on the solidifying ranges of the alloys are given in columns 3 and 4 of Table II., and are shown graphically in Plate XVIII.

*Beginning of Solidification.*—The points marking the beginning of solidification lie on a smooth curve, AB, if allowance is made for experimental errors. The curve is slightly convex upwards, and is represented by the equation

$$t = 1505 - 54.65C - 7.1C^2,$$

where  $t$  is the temperature in degrees centigrade, and  $C$  is the carbon percentage.

Of the thirty-three alloys the maximum deviation of an observation is  $8^{\circ}\text{C}$ ., and in the case of thirty is  $5^{\circ}\text{C}$ . or less. From the curve the following short table has been calculated—

Percentage Carbon. Pure Iron.	Beginning of Solidification. Degrees Centigrade.
0	1505
1	1444
2	1368
3	1278
4	1173
4.3	1139

*End of Solidification.*—The end of solidification is shown by the lines Aa, aB. Where the carbon content is above 2 per cent. this is always marked by a recalescence, as noted on page 230, which attains a maximum at 4.3 per cent. The extreme cases are seen in Fig. 3, M and N. In all cases the top of the recalescence has been taken. From 2.1 to 2.5 per cent. the temperature appears to rise from about  $1105$  to  $1135^{\circ}$ ; beyond this it is nearly constant.

Where the carbon content is less than 2 per cent. there is no recalescence and the difficulty of interpreting the curves is largely increased. With low carbon content (*cf.* Fig. 3, L) the change in slope is fairly well marked, and the uncertainty is probably not greater than about  $10^{\circ}$ . As 2 per cent. carbon

TABLE

*The Range of Solidification and the*

1.	2.	3.	4.	5.	6.	7.
Alloy No.	Carbon per Cent.	Range of Solidification.		Ar.m.c.	Ar3.	
		Beginning.	End.		Beginning.	Maximum.
1	0.01	...	...	...	901	900
2	0.02	1504*	1470*	...	900	890
3	0.05	...	...	...	905	884
4	0.12	1504†	1470†	...	894	838
5	0.16	1498†	1465†	...	872	837
6	0.17	1497†	1450†	...	...	...
7	0.24	1492†	1448†	...	890	Merged
8	0.38	1479†	1416†	...	...	...
9	0.47	1482†	...	...	...	...
10	0.53	1473†	1404†	...	...	...
11	0.61	1469†	1394†	...	...	...
12	0.80	1457†	1351†	...	...	...
13	0.80	1454†	...	...	...	...
14	0.81	1460†	1351†	...	774	Merged
15	0.93	1443†	...	...	774	...
16	1.31	1426†	1286†	883	774	"
17	1.51	1406†	1244†	911	768	"
18	1.69	1388†	...	965	774	...
19	1.81	1383†	...	...	...	...
20	1.85	1383†	1179†	(1015) 1090	783	Merged
21	1.97	1367†	...	(1042)	...	...
22	2.12	1350†	1110†	...	...	...
23	2.21	1354†	1107†	...	801	Merged
24	2.25	1352†	1122†	...	...	...
25	2.25	1348†	1122†	...	...	...
26	2.47	1330†	1134†	1035	801	Merged
27	2.63	1305†	...	1040	801	...
28	2.67	1306†	...	...	...	...
29	2.74	1300†	1139†	...	...	...
30	2.85	1292†	1139†	1058	...	Merged
31	3.03	1277†	1139†	...	777	"
32	3.29	...	1141†	...	...	...
33	3.42	1238†	1114†	1058	790	Merged
34	3.51	1230†	1136†	...	...	...
35	3.87	1190†	1144†	1090	770	Merged
36	3.98	1171*	1138*	1087	...	...
37	4.37	1136*	1136*	...	...	...
38	4.50	1146*	1146*	1087	777	Merged

\* Thermojunction M<sub>5</sub> platinum platinum 10 per cent. iridium.† " M<sub>5</sub> " " " " "‡ " M<sub>4</sub> " " " " rhodium.

The temperatures in brackets in columns 5 and 11 were obtained by direct cooling. All other temperatures in columns 5-12 were obtained by differential cooling.

## II.

*Critical Ranges of Iron Carbon Alloys.*

8.	9.	10.	11.	12.	Alloy No.
Ar2.		Ar1.		Ar0.	
Beginning.	Maximum.	Beginning.	Maximum.	Beginning.	
784	762	...	...	616	1
796	762	...	...	600	2
780	762	...	...	...	3
774	762	693	688	600	4
771	762	697	693	576	5
...	...	...	...	...	6
...	762	696	693	611	7
778	762	700	699	...	8
777	762	...	703	587	9
762	730	...	700	617	10
780	Merged	Merged	699	593	11
...	...	...	(704)	...	12
...	...	...	(695)	...	13
...	Merged	Merged	706 (705)	...	14
...	"	"	699	587	15
...	"	"	(711) 695	600	16
...	"	"	(713) 684	587	17
...	...	...	(708) 710	...	18
...	...	...	...	...	19
...	Merged	Merged	(711) 711	...	20
...	...	...	(710)	...	21
...	...	...	(714)	...	22
...	Merged	Merged	714	610	23
...	...	...	...	...	24
...	...	...	(714)	...	25
...	Merged	Merged	708	622	26
...	...	...	716	610	27
...	...	...	...	...	28
...	...	...	...	...	29
...	Merged	Merged	716 (715)	613	30
...	"	"	702 (717)	610	31
...	...	...	...	...	32
...	Merged	Merged	703 (714)	610	33
...	...	...	...	...	34
...	Merged	Merged	(716) 716	600	35
...	...	...	713	604	36
...	...	...	(714)	...	37
...	Merged	Merged	715	616	38

Ar.m.c. represents separation of massive cementite.

Ar3 " change from  $\gamma$  to  $\beta$  iron.Ar2 " " "  $\beta$  to  $\alpha$  "

Ar1 " " " hardening carbon to pearlite carbon.

Ar0 ?

is approached the change in slope is less well defined, and the temperatures given are in doubt to the extent of 20° or 30°.

According to the results given the solubility of carbon in iron at about 1100° lies between 1.97 and 2.12 per cent. This fully confirms the results obtained by Roberts-Austen and Stansfield.

Only one alloy (C = 4.5 per cent.) above the eutectic point has been prepared.

*Methods of Analysis of the Alloys.*—In taking samples of the alloys the outside  $\frac{1}{8}$  inch was rejected, using a  $\frac{1}{8}$ -inch twist drill. Samples were taken from this depth to the centre of the alloy in three places on an average. Careful tests were made to ascertain the extent of liquation, and it was shown that this does not occur, except in a few cases, to any very marked extent, and not always in the same direction, e.g., the carbon in the centre of the alloy is generally, but not always, higher than at the exterior. The drillings of alloys Nos. 16, 21, 22 and 34 were sieved, and proportional parts by weight of the fine and coarse sievings estimated separately for carbon. The drillings of alloys Nos. 36, 37, 38 were ground to a uniform fine powder in a porcelain mortar, as recommended for pig irons by Blair (*Chemical Analysis of Iron*, Third Edition, p. 15).

*Total carbon* was estimated by solution of the samples in potassium copper chloride acidulated with hydrochloric acid (cf. Blair, p. 150), and combustion of the separated carbon in oxygen.

*Graphite* was determined by dissolving the drillings in nitric acid (specific gravity, 1.20), and following the method given by Blair, p. 167.

The estimation of *sulphur* was made by dissolving the drillings in hydrochloric acid, absorbing the hydrogen sulphide with alkaline lead nitrate, and weighing as barium sulphate (cf. Blair, p. 59).

*Silicon* was determined by dissolving in nitric acid (1.20 specific gravity), baking, evaporating with hydrochloric acid to render silica insoluble, and estimating by evaporation with hydrofluoric acid (cf. Blair, p. 72).

*Phosphorus* was estimated as ammonium phosphomolybdate (cf. Brearley and Ibbotson, "Analysis of Steel Works Materials," p. 49).

*Manganese*, which was estimated by the bismuthate method, was only present in traces.

The results quoted in Table I. are in every case the mean of at least two, and sometimes as many as four analyses. They show that the ordinary impurities in the materials used have hardly been altered by the melting process, and that carbon and iron are the only two variables that need be taken into account.

### THE CRITICAL RANGES OF THE ALLOYS.

We use the expression "critical range" in preference to "critical point," as applied to the alloys of iron and carbon, because it appears to us to express the facts more accurately. Reasons for this will be given in a subsequent part of the paper.

*Method of taking Cooling Curves.*—The principle of the method was that introduced by Roberts-Austen and Stansfield, viz. differential cooling between the alloy and platinum cooling under the same conditions. The cooling curves have been taken in air. Under these conditions the surface of the metal becomes oxidised, but not to an extent sufficient to mask the critical changes.

The type of furnace made in the laboratory is shown in Fig. 4 and Plate XIX. It consists of an unglazed porcelain tube 16 inches in length, 1 inch in diameter, C, heated electrically by a coil of nickel wire, 1.5 mm. diameter, carrying about 20 ampères, and insulated by crushed quartz, Q, contained in a wide porcelain tube, E, closed by furnace-ends, D. The whole was contained in a magnesia steam-pipe covering, M. The wire is wound over the central 9 inches of the tube, the distance between the coils gradually increasing from the outside to the centre in order to compensate for the cooling effect of the ends. At the thermal centre of such furnaces there is usually a space of at least 2 inches where, between 1000° and 600° C., the temperature variation is not greater than about 3° C. A temperature of 1000° can be reached with about 740 watts.

Cylinders of the alloys,  $\frac{5}{8}$  in. long and  $\frac{5}{8}$  in. in diameter, were turned for the cooling curves. The platinum cylinder, A, was drilled with one hole for the insertion of one end of a differential thermojunction, the other end of which was placed in a hole drilled in the alloy, B. The leads, F, from these were hard-soldered to copper wires placed in an ice-box, and connected with the galvanometer, G. A second hole was drilled in B for an independent thermojunction connected with the potentiometer. With this arrangement galvanometer G indicates differences of temperature between the platinum and the alloy. While the potentiometer gives the actual temperatures of the latter.

At about  $1000^{\circ}$  C. porcelain conducts electricity appreciably,

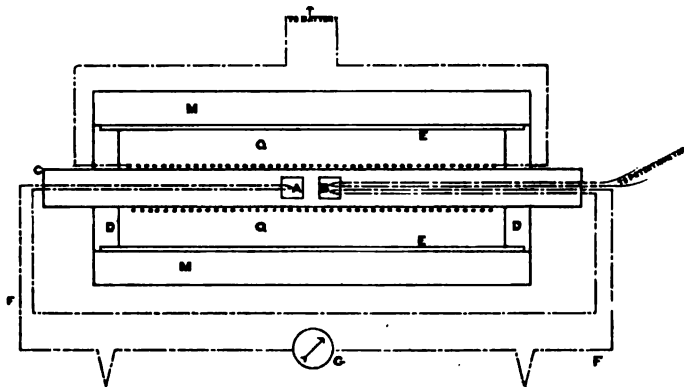


FIG. 4.

and accordingly the two cylinders were mounted on a rail made of fused quartz. Several cooling curves were taken from  $1250$ – $1300^{\circ}$  C., and at these temperatures the quartz devitrifies, and requires to be occasionally reglowed in an oxy-coal-gas flame.

The temperatures from which cooling curves can be taken by this method are limited by those at which the alloys begin to melt. Thus for all alloys above 2 per cent. carbon the limit is fixed at  $1100^{\circ}$ – $1140^{\circ}$ . The heating of the alloys to this temperature takes about  $1\frac{1}{2}$  hours. Our practice has been to maintain them for about half-an-hour in this state, in order to allow chemical equilibrium to be reached, and then to cut off the heating current completely. The cooling to  $500^{\circ}$  C. occupies about 1 hr. 20 min.

In the case of two metal cylinders of equal size, specific heat, and emissivity, and in a uniformly-heated furnace, the cooling curve would, in the absence of critical changes, be a vertical straight line; and if these conditions were not fulfilled, the cooling curve would be a smooth curve approximating to a straight line, but inclined to the vertical. This has been experimentally tested by taking a cooling curve with nickel and platinum as the metals; the curve was inclined to the vertical, and no departure from a straight line was noticeable. This fact has enabled us to interpret with confidence those parts of the curves where small differences of temperature are indicated. It is interesting to note that platinum can be replaced by nickel in the differential cooling method between  $1200^{\circ}$  and  $500^{\circ}$ .

In every case two cooling curves, and sometimes three and four, have been taken, the position of the two cylinders being altered between each cooling curve by moving the quartz rail. In the diagrams the temperature of the alloy is plotted vertically, while movements of the differential galvanometer, caused by differences of temperature between the two cylinders, are plotted horizontally.

Typical cooling curves of nine alloys are appended (Fig. 5). The deflections of the galvanometer connected with the differential junction were in some cases considerable, *e.g.* at the Ar1 change of alloy No. 15, a movement of 400 millimetres (16 inches) on the scale was recorded. The complete results are given in columns 5–12, Table II. Where possible the beginning and the maximum velocity of heat evolution at each critical change is stated. The former is indicated by the temperature at which the curve begins to change its slope, the latter at which the slope changes from concave to convex. The ends of the critical ranges have not been given, as it appears to us that these depend entirely on the rate of cooling.

Reference to the typical curves shows that the critical changes of the iron-carbon alloys fall into two classes. The changes of the one type are sufficiently rapid to complete themselves within a narrow range of temperature. Instances of these are the Ar3 change in the case of alloys Nos. 1 and 2, and the Ar1 change for all alloys with carbon percentage above 0.3. To these changes the expression "critical point" may be quite properly



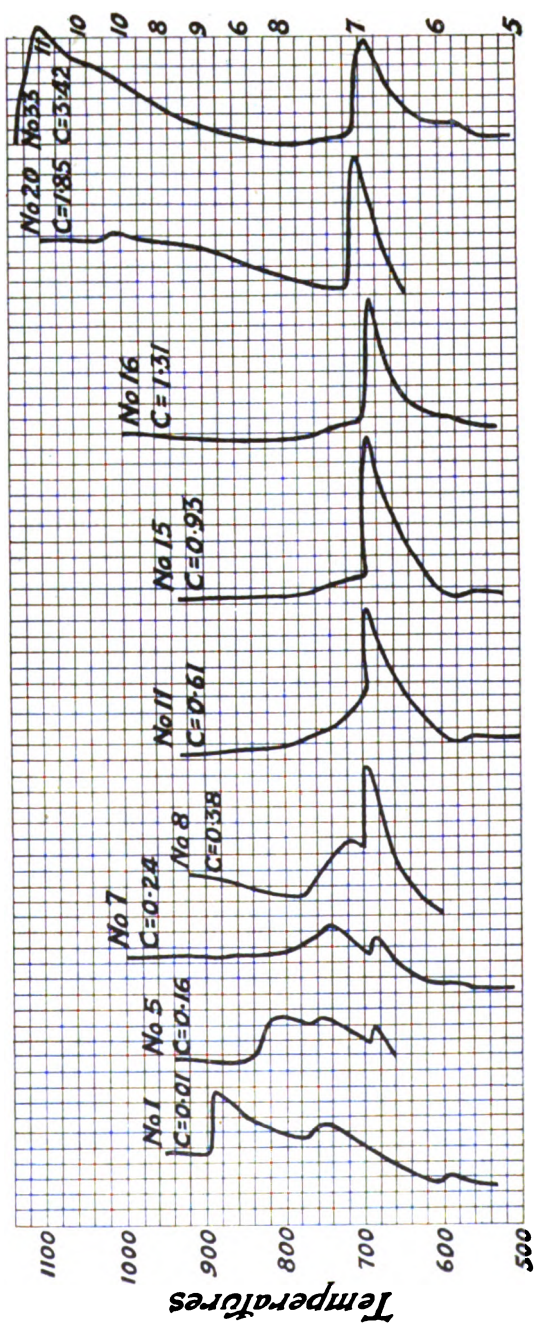


FIG. 6.

applied. The other class includes the Ar.m.c. change (the separation of massive cementite), the Ar2 change, *i.e.* the appearance of magnetism on cooling, and that designated as Ar0. We have never found that any of these changes occurs rapidly in any alloy. Each extends over a not inconsiderable range of temperature. It should further be noted that if the carbon in the alloy is 0.1 per cent. and upwards, the Ar3 change must be removed from the former to the latter class (*cf.* curves of alloys Nos. 5 and 7). In the majority of cases, therefore, critical range expresses the facts more accurately than critical point.

The various critical changes will now be considered with reference to Roozeboom's diagram. The fact that we shall consider these in terms of the phases discussed by Roozeboom is not to be taken as a committal on our part to the adoption of his views. Plate XVIII. gives our results together with his diagram. It should be stated that the temperature of the beginning of the critical changes Ar.m.c. and Ar0 has been plotted, but that of the maximum velocity of Ar3, Ar2, and Ar1 has been chosen because it enables a comparison with the results of previous workers to be more easily made. Further, Ar.m.c. and Ar0 are changes in which a maximum velocity has not been detected.

*Ar.m.c.—Separation of Massive Cementite*—Column 5.—A typical case is seen in the curve for alloy No. 16, where the separation begins about 883°. The initial formation of cementite from the homogeneous solid solution of carbon in iron (martensite), *i.e.* for carbon percentages between 0.9 and 1.7, may be represented quite as well by a straight line as by the curve given by Roberts-Austen and Stansfield (Plate V., *Fifth Alloys Research Report*). For carbon percentages between 1.85 and 4.50 the temperature of initial change rises from about 1030° to 1090°. In these cases there is evidence to show that between 1140° and the temperature at which martensite and graphite yield cementite, the solubility of carbon in martensite steadily decreases, the separation of graphite being marked by a steady evolution of heat (*cf.* curve of alloy No. 20), which, however, is not sufficient to mask that set free in the formation of cementite (same curve).

An inspection of the cooling curves does not enable us to

decide whether in all cases the formation of massive cementite continues progressively until the change from hardening carbon to carbide carbon takes place at about  $710-715^{\circ}$ , the carbon percentage of the martensite then being 0.9 per cent. Between 0.9 and 1.85 the continuity of the change is fairly apparent, but for alloys between 2.1 and 4.5 per cent. there are indications in several cases of a slackening or completion of the reaction at about  $900^{\circ}$  C. In two cases, viz. alloys Nos. 35 and 38, a considerable evolution of heat at about this temperature was noticed. Neither of these facts are explained by Roozeboom's diagram.

In very nearly all alloys, with carbon percentage 0.8 and upwards, a small evolution of heat was noticed at temperatures varying between  $770^{\circ}$  and  $800^{\circ}$ . Professor H. Le Chatelier\* stated in 1898 that his measurements of the electrical resistances of highly carburetted steel indicated the existence of a change "near  $800^{\circ}$ ," and commented on the fact that if the change occurred slowly it might not cause an appreciable retardation on cooling. Possibly the confirmation of the results of his observations is to be found in this small thermal change.

*Ar3* (Columns 6 and 7).—Our results indicate that the temperature at which this change begins is approximately constant, viz. between  $900^{\circ}$  and  $890^{\circ}$ ; although the maximum falls as carbon percentage rises from 0.01 to 0.24. In agreement with previous workers, we find that in alloy No. 8 (carbon percentage 0.38) *Ar3* is merged into *Ar2*.

*Ar2* (Columns 8 and 9).—The temperature of incipient change varies between  $795^{\circ}$  and  $762^{\circ}$ ; that of maximum velocity of heat evolution is constant at  $762^{\circ}$  for alloys 1–9, and then falls rapidly.

*Ar1* (Columns 10 and 11).—The temperature of maximum velocity of heat evolution rises gradually, from  $688^{\circ}$  to  $717^{\circ}$ .

*Ar0*.—Our results fully confirm the existence of this change, which was detected by Roberts-Austen and Stansfield,† in pure electro iron and steel containing 0.54 per cent. carbon. Its range is, however, hardly so wide as they state, viz.  $100^{\circ}$  C. It does not appear to us to extend over more than  $50^{\circ}$  C.

\* *The Metallographist*, vol. i., 1898, p. 63.

† *Fifth Alloys Research Report*, p. 51.

We have investigated the question as to whether this change is associated with an alteration of physical structure. Two sections each were cut from alloys Nos. 1, 8, 14, and 18. The one set was quenched in iced brine from  $650^{\circ}$ , *i.e.* before the ArO change begins; the other set was quenched from  $500^{\circ}$ , *i.e.* after its completion. The sections were polished and etched, Nos. 1 and 8 with 5 per cent. picric acid in alcohol, Nos. 14 and 18 by polish attack on parchment with 2 per cent. ammonium nitrate in water. No differences of structure in any of the specimens were detected.

### HEATING CURVES.

In the case of certain alloys, heating as well as cooling curves have been taken, but the former method gives results less well defined than those of the latter. In the appended table Ac denotes change taking place on heating, Ar that taking place on cooling.

*Comparison of Heating and Cooling Curves.*

Alloy No.	Beginning.		Beginning.	
	Ar3	Ac3	Ar1	Ac1
1	901	908	...	...
2	900	900	..	...
3	905	908	...	...
8	...	...	724	724
20	...	...	718	729
36	...	...	728	728
38	...	...	715	728

For low carbon alloys, *e.g.* Nos. 1–3, the temperatures, at which the changes Ar3 and Ac3 begin, appear to be nearly the same. In the case of the changes Ar1 and Ac1 there appears to be a lag of a few degrees.

### CONCLUSIONS.

The results of the experiments are shown by the dots in Plate XVIII., on which is also given the outline of Roozeboom's diagram.

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So far as our results go, they confirm, broadly speaking, the accuracy of Roozeboom's diagram, subject to the following qualifications:—

1. The melting point of iron is about  $1505^{\circ}$ .
2. AB is a smooth curve, slightly convex upwards.
3.  $\alpha$ B is not a horizontal line, but rises from  $\alpha$  to B.
4. SE may be represented quite as well by a straight line as by a curve.
5. PK is not a straight line, but rises from P to K.

Further, our results indicate that the diagram will be amplified in certain parts when the equilibrium between the various phases has been more fully studied, viz. on account of—

1. The small thermal change at about  $790^{\circ}$  for alloys with carbon content 0.8–4.5 ;
2. The slow thermal change at about  $600^{\circ}$  found over the whole range of alloys ;
3. The evolutions of heat at about  $900^{\circ}$  found in alloys Nos. 35 and 38.

Part of the expense of this research has been defrayed out of the grant to the Laboratory from the Iron and Steel Institute.

We acknowledge with pleasure the interest taken in our work by Dr. Glazebrook, the Director of the Laboratory. We have great pleasure in thanking Mr. L. F. Richardson for help in much of the work, particularly the chemical analyses, and Dr. J. A. Harker for advice as to temperature measurements.

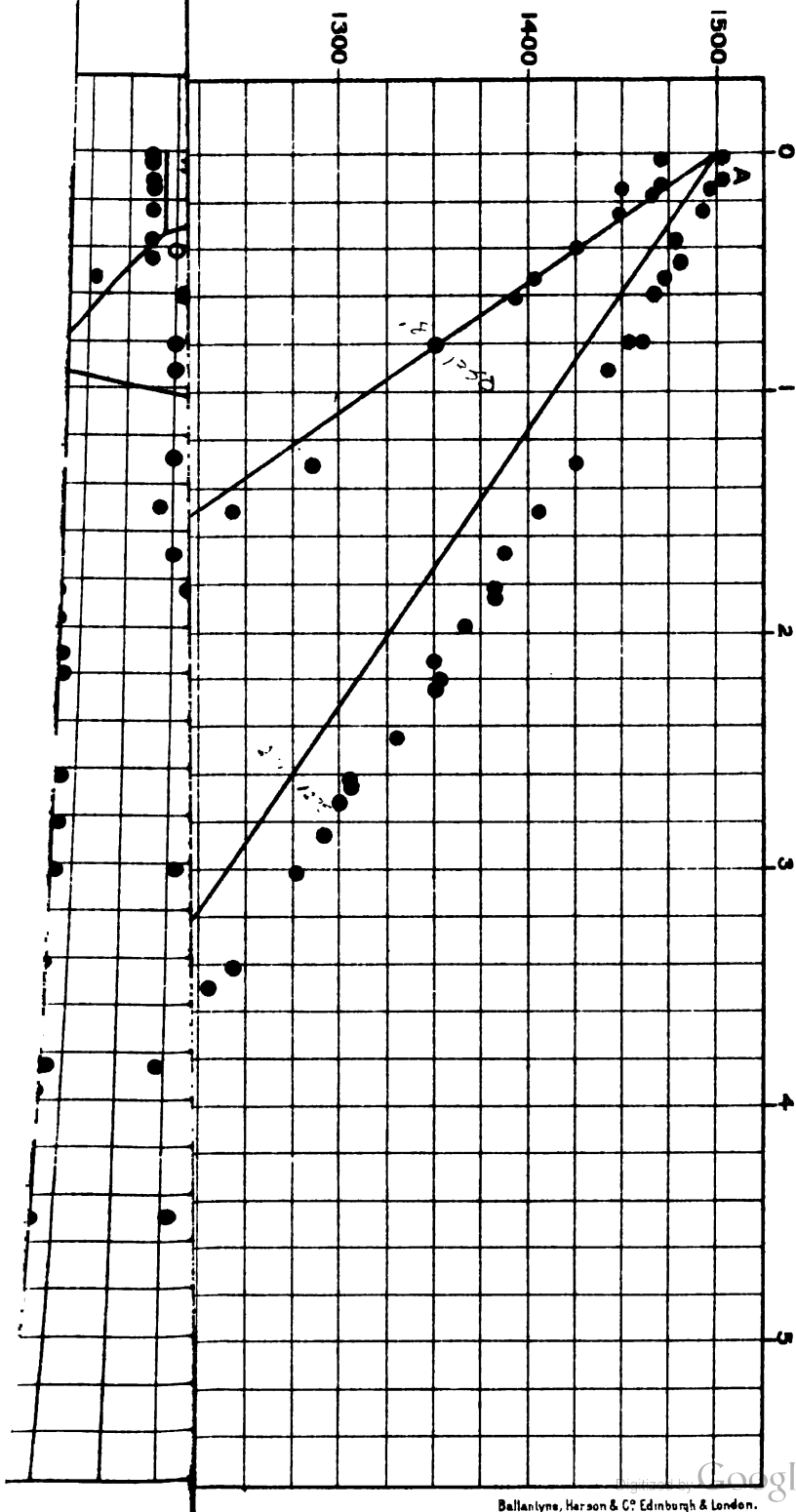


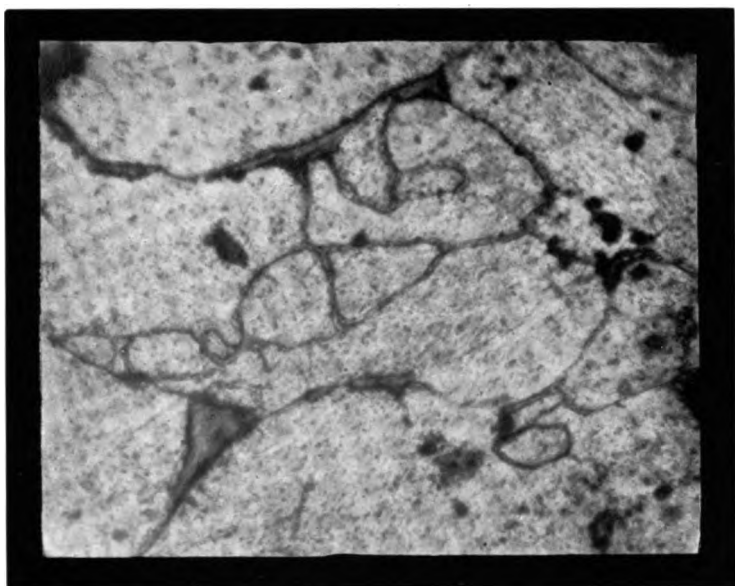


PLATE XIX.

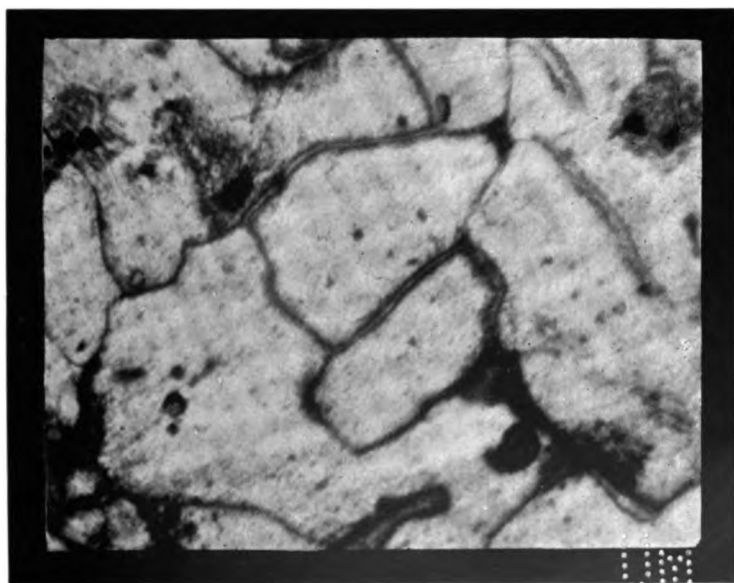




20



**FIG. 1.**—Nearly pure iron, as cast.  
Casting Temperature, 1653° C.



**FIG. 2.**—Nearly pure iron, as cast.  
Casting Temperature, 1613° C.  
Magnified 360 diameters.

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# PLATE XXI.

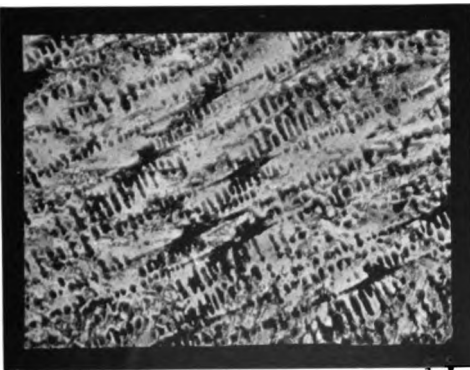


FIG. 3.—White cast iron. Magnified 58 diameters.  
Casting Temperature, 1320° C.  
Maximum Stress, 10·7 tons.

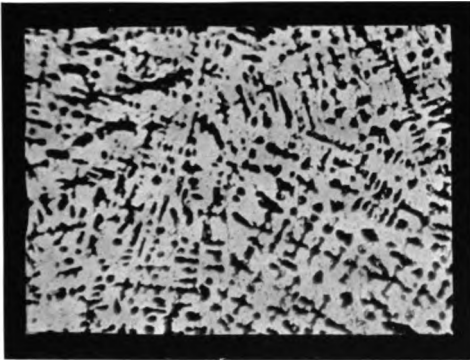


FIG. 4.—White cast iron. Magnified 58 diameters.  
Casting Temperature, 1230° C.  
Maximum Stress, 15·9 tons.

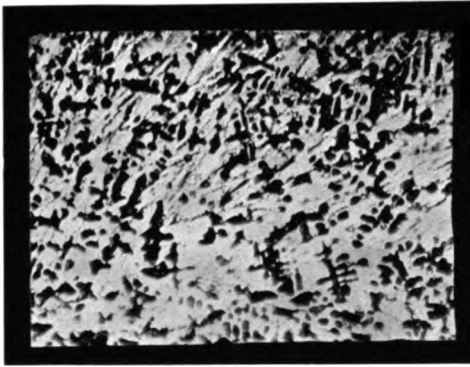


FIG. 5.—White cast iron. Magnified 58 diameters.  
Casting Temperature, 1120° C.  
Maximum Stress, 12·1 tons.



# PLATE XXII.

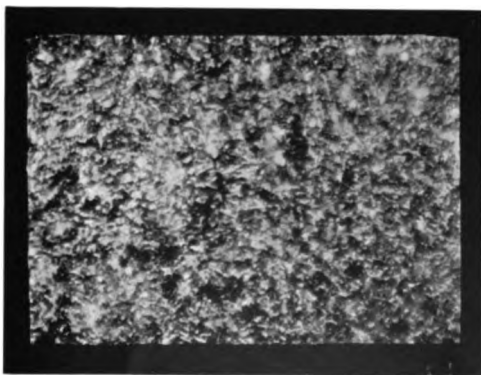


FIG. 6.—White cast iron. Annealed.  
Magnified 58 diameters.  
Casting Temperature, 1320° C.  
Maximum Stress, 20.6 tons.

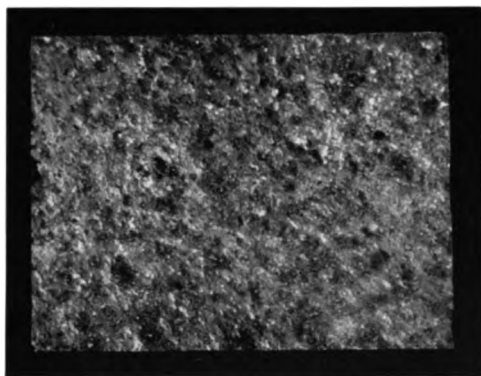


FIG. 7.—White cast iron. Annealed.  
Magnified 58 diameters.  
Casting Temperature, 1230° C.  
Maximum Stress, 29.2 tons.

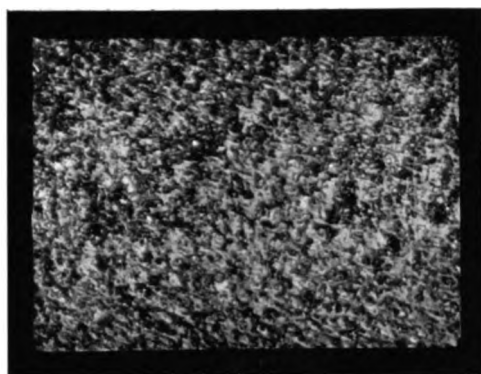


FIG. 8.—White cast iron. Annealed.  
Magnified 58 diameters.  
Casting Temperature, 1120° C.  
Maximum Stress, 26.5 tons.

ND

# PLATE XXIII.

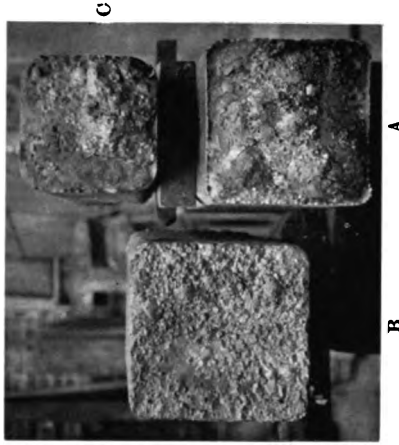


FIG. 21.—Three Siemens Steel Ingots.  
A "Hot." B "Fair." C "Cold."

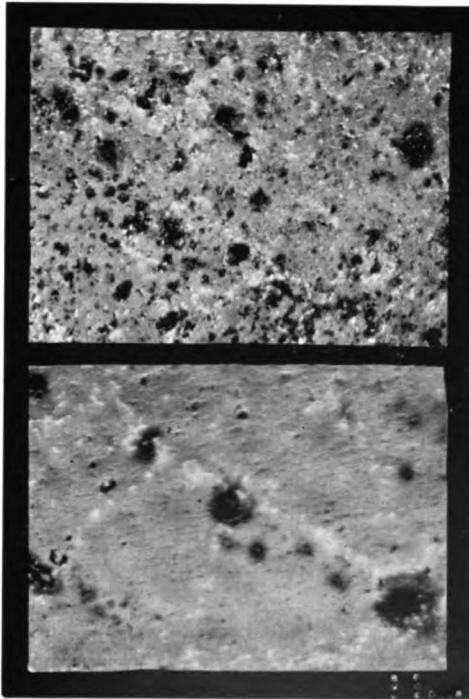


FIG. 9.—Grey cast iron. Heat tinted.  
Magnified 58 diameters.  
Casting Temperature, 1400° C.  
Maximum Stress, 9.7 tons.

FIG. 10.—Grey cast iron. Heat tinted.  
Magnified 58 diameters.  
Casting Temperature, 1245° C.  
Maximum Stress, 10.6 tons.



11

PLATE XXIV.

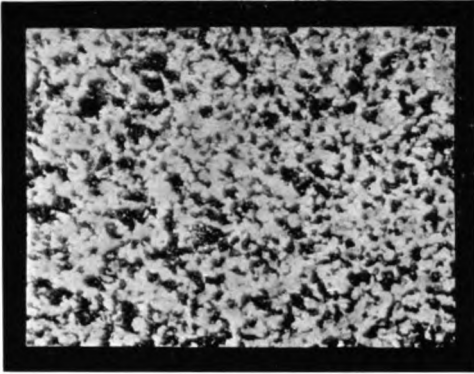


FIG. 13.—Steel, No. 86A.  
Elongation per cent., 27.5.  
Magnified 58 diameters.

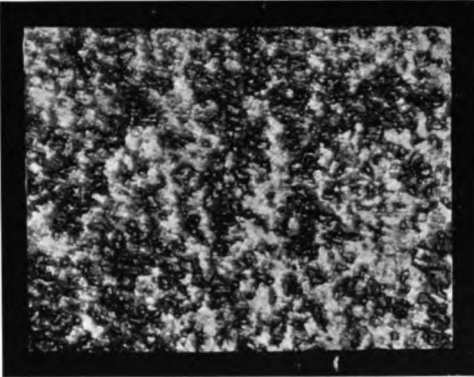


FIG. 12.—Steel, No. 85A.  
Elongation per cent., 33.5.  
Magnified 58 diameters.

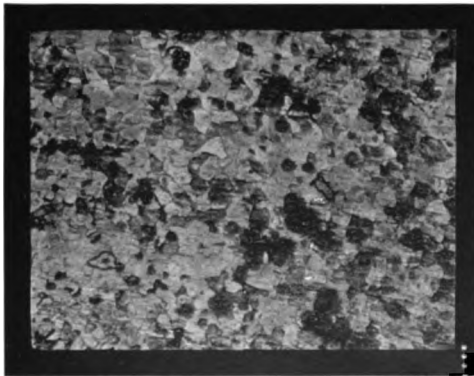


FIG. 11.—Steel, No. 84A.  
Elongation per cent., 15.5.  
Magnified 58 diameters.

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PLATE XXV.

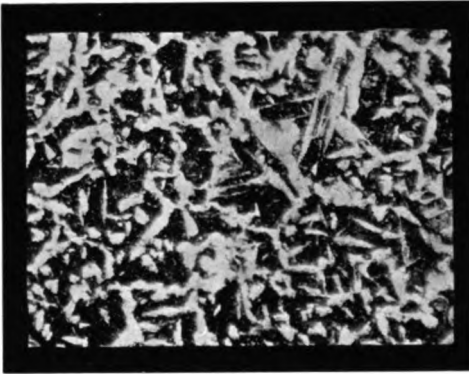


FIG. 16.—Steel, No. 89A.  
Elongation per cent., 6.5.  
Magnified 58 diameters.

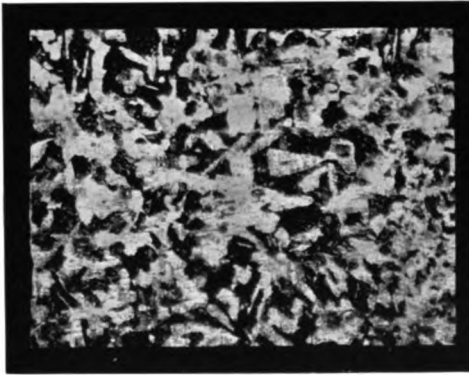


FIG. 15.—Steel, No. 88A.  
Elongation per cent., 20.0.  
Magnified 58 diameters.

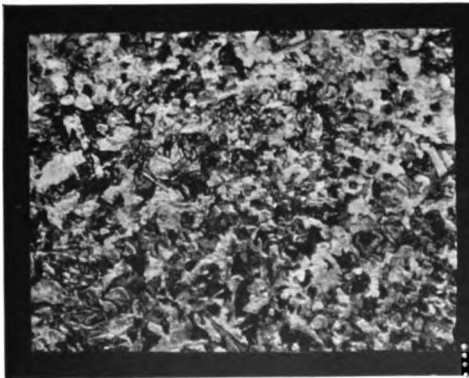
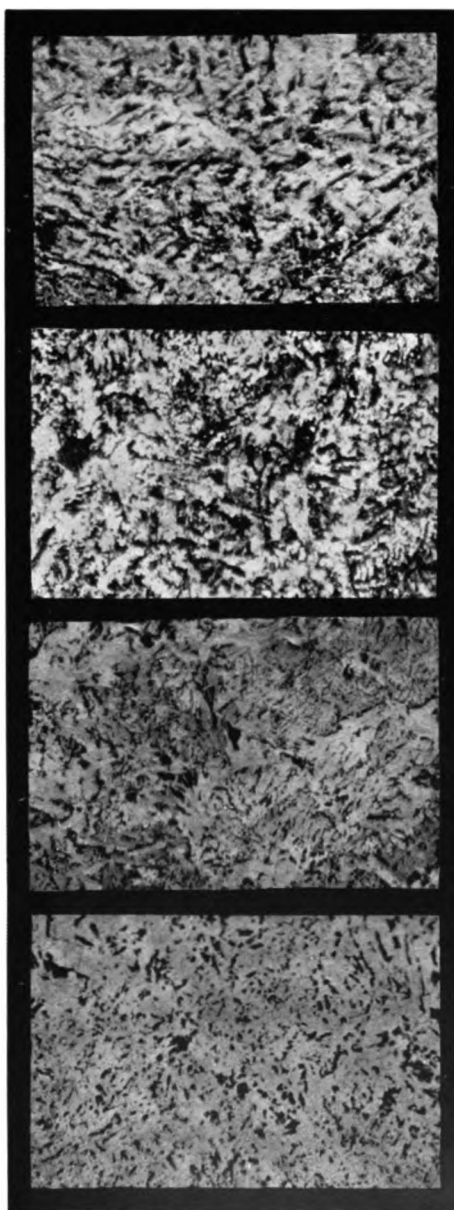


FIG. 14.—Steel, No. 87A.  
Elongation per cent., 22.5.  
Magnified 58 diameters.

24

# PLATE XXVI.



**FIG. 17.—Steel, No. 90.**  
Maximum Stress, 14·2 tons.  
Steel in the cast condition.  
Magnified 58 diameters.

**FIG. 18.—Steel, No. 91.**  
Maximum Stress, 21·5 tons.  
Steel in the cast condition.  
Magnified 58 diameters.

**FIG. 19.—Steel, No. 92.**  
Maximum Stress, 21·4 tons.  
Steel in the cast condition.  
Magnified 58 diameters.

**FIG. 20.—Steel, No. 93.**  
Maximum Stress, 17·5 tons.  
Steel in the cast condition.  
Magnified 58 diameters.



*DISCUSSION.*

Professor J. A. EWING (Greenwich) said that he had read the paper with very great interest. It was one of first-rate importance in settling points in regard to which there were gaps in their previous knowledge. He would like to congratulate most heartily the authorities and staff of the National Physical Laboratory on the completion of this exceedingly important and laborious piece of work. The existing data were by no means complete, and the matter was one which lay in that border-land between pure science and practice, which it was the function of the National Physical Laboratory to come in and possess. He thought that the results of the investigation might be made still more valuable to the scientific and engineering public if a fuller publication of them were given. He confessed to having found too short the paper in which, with conspicuous modesty, Dr. Carpenter and Mr. Keeling had recorded a long and laborious research; in particular, the usefulness of the paper would be very much enhanced if every one of the cooling curves were reproduced. The real value of such a research, of course, lay in the recorded cooling curves. The interpretation which was put upon those curves was, to a great extent, a personal matter with the individual interpreter. What they wanted was to see the curves themselves, and they wanted to see them reproduced on a larger scale than the selected curves which were actually reproduced on one page of the paper. He ventured to press strongly on the authors and on the authorities of the Institute the desirability of a fuller publication. Perhaps the most interesting new point which the research brought out was the point alluded to by Dr. Carpenter, namely, the development of heat, which began during cooling at about  $800^{\circ}$  or  $780^{\circ}$ . There was in the selected curves which appeared in the paper a very distinct break in the cooling line in nearly if not every instance at that point: a change of slope occurred in the cooling line, which indicated that there was at that point the beginning of an evolution of heat in the sample. This evolution, however, went on continuously in most cases until the great evolution, known as Ar1, followed. The whole region, in fact, from  $800^{\circ}$  down to Ar1 appeared to be a region in which there was a progressive evolution



of heat going on in nearly every case. The physical interpretation of this result was still wanting. If members would turn to the diagram in which the general results were recorded they would notice this evolution of heat, beginning at about  $780^{\circ}$  or  $800^{\circ}$ , indicated there by means of a series of dots extending into the region to the right, which was generally spoken of as the region of mixed martensite and cementite. Going to the extreme left of that line, on practically much the same level of temperature, they had the points which were generally associated with the change of iron from the alpha to the beta condition, if one might accept Mr. Osmond's nomenclature. Between those two, namely, in the V of the transformation curve, there were two points apparently on the same level, and he had just noticed from such inspection as he had been able to make himself of the recorded cooling curves, that in point of fact there was at least one more point on the same level not marked in that sheet. That was the alloy, with 0.61 per cent. of carbon, which showed a very distinct break in that cooling curve, indicating the beginning of an evolution of heat at just that level of temperature. If one filled in that point which was missing in the diagram one would see that a nearly horizontal line at about  $780^{\circ}$  might fairly be said to extend straight across the diagram throughout the whole range of carbon content, from nothing up to the highest that the research dealt with. The inference seemed *prima facie* reasonable that whatever that change was it was essentially the same as the change they were accustomed to call Ar2, in dealing with carbonless or nearly carbonless iron. It would be interesting to know whether the gain of magnetic quality began in high carbon steels at this point. They knew that it was at the point Ar2 in nearly carbonless iron. Did it happen at the same point in alloys with a comparatively high carbon content? Another point on which he would like further information was with regard to the identity or difference between successive cooling operations in one and the same specimen. It would be in the recollection of some of the members of the Institute that Sir William Roberts-Austen, in a paper dealing with the cooling of electrolytically deposited iron, pointed out that in his experience he did not reproduce the same curve in successive coolings, but that the arrest points were distinctly less

marked in subsequent coolings than in the first. He would like to know, also, whether the authors had experimented with more than one sample of practically the same carbon content in each case. With regard to the method of testing there was just one remark which occurred to him. He had not had the advantage of seeing in operation the apparatus which the authors had used, but if he understood rightly the recorded cooling curves depended upon personal observation which could only be taken at successive intervals of time; they might be short intervals, but what was got was not really a continuous curve but a succession of points from which a continuous curve might be sketched. It seemed to him that that was in some respects an inferior method of working to that of photographic registration. In photographic registration one had an absolutely continuous record, leaving nothing to the personal equation of the observer. That was particularly important where comparatively small changes of gradient in the curve might have a really important physical significance. In operating as these observers had done, they probably got a more open range of scale than would have been practicable had photographic registration been resorted to. But he was not sure that he would not prefer a photographic curve, on a somewhat smaller scale, to a larger one depending on personal observation. It was interesting to notice the confirmation that was given in these experiments to Sir William Roberts-Austen's observation of an arrest at about  $600^{\circ}$ , indicating a change below the great carbon transformation. If one turned to the recorded experiments of Dr. Morris, on effects of temperature on the magnetic quality of iron, one would observe a corresponding change in the magnetic susceptibility at the same temperature. In some observations which Mr. Rosenhain and he had made in Cambridge some years ago, in which they watched, under the microscope, the cooling of nearly carbonless iron, they observed a remarkable change take place over the surface of the specimen which was apparently also connected with that point. He would once more congratulate the National Physical Laboratory on this most valuable piece of work.

Sir EDWARD CARBUTT, Bart., Member of Council, wished to congratulate Dr. Carpenter and the Institute, because the

paper was the result of work done at the National Physical Laboratory, which their able director, Dr. Glazebrook, had brought into such a good position. It showed that at any rate the money which the Government had granted to them, viz., only £4000 a year, was being very well spent. The Iron and Steel Institute were subscribing £200, the Mechanical Engineers were doing the same, and the Civil Engineers were contributing some £600 a year. So that he thought that the Institute might be congratulated upon the fact that they were getting some very good results from the small sum of money which was spent. But they would like to see the Iron and Steel Institute support them with the Government to get that grant very largely increased. They were hampered entirely by that very small grant, and they felt that, if they had more money, those who were representing the different institutions, such as the two able representatives of their council on the National Physical Laboratory, the Right Hon. Sir Bernhard Samuelson, Bart., and Mr. R. A. Hadfield, Mr. Maw and himself representing the Institution of Mechanical Engineers, and Sir John Wolfe Barry and Sir W. H. Preece representing the Institution of Civil Engineers, all working together, should be able to carry on the National Physical Laboratory with very great success if they could only persuade the Government to give them a little more money. He would like to say that Dr. Carpenter was in the proud position of having been chosen by the Carnegie Research Committee as one of the gentlemen to receive £100 to continue his researches. Then owing to the action of Professor Glazebrook they had obtained the services of Mr. Longmuir, who was a Carnegie Research Scholar; and he thought, with Dr. Carpenter and Mr. Longmuir and the other gentlemen at the National Physical Laboratory, they might be able to arrive at results which would be of great benefit to the Iron and Steel Institute. He begged to offer his congratulations to Dr. Carpenter for his very able paper.

Professor H. LE CHATELIER (Paris) said that Dr. Carpenter's paper was one of the most remarkable contributions that had been made on the subject of fusion points and the transitional forms of steel. If on a number of points he did no more.

than confirm the experimental researches of Osmond, and of Roberts-Austen earlier, or the theoretical views of Bakhuis Roozeboom, he had at least done so with a degree of exactitude which would doubtless end, for a long time, all fresh discussion on the subject. He brought, likewise, new views to bear on the existence of the more indetermined transformations, noticed hitherto in the case of electrolytic iron only, by Roberts-Austen. It could only be regretted that Dr. Carpenter had not given a graphic record of his results, presented quite independently of the existing diagram of Roozeboom. Some confusion might arise in the minds of casual readers, who might rest content with a hurried inspection of his diagram. They might imagine him to have done no more than confirm that of Roozeboom, without having added anything fresh thereto. As a matter of fact this was so; the curve at E relating to the separation of graphite, the position of which has for a long time been a matter of controversy, appeared in particular to have been deliberately omitted in the diagram. The points observed lay in reality along the continuation of the curves S, E, in the direction of its juncture with the line  $aB$ .

It was to be hoped that before long a large number of equally accurate papers might appear in connection with metallurgical science.

Professor J. O. ARNOLD (Sheffield) said the paper was practically the first fruits of the National Physical Laboratory, and he had naturally looked forward to it with great interest; and any remarks which he might make concerning it must not be taken in the nature of hostile criticism. Dr. Carpenter and he had been very carefully through the paper that morning, and it must be regarded as tentatively putting forth observations bearing upon certain theories, and not to be regarded as final at all. Any remarks which he might make would not be in the nature of hostile criticism, but rather to bring more experience to bear on the subject in connection with the published and unpublished work from the University College, in order to make still more valuable the future work in that direction. In the first place, he would very sincerely congratulate Dr. Carpenter and Mr. Keeling on the title of the paper. They spoke of "critical

ranges," and he thought that was a very happy expression. If people, instead of talking about the alpha, beta, gamma, and delta iron, would speak of the alpha, beta, gamma, and delta ranges, there would be no trouble. He thought that was an exceedingly happy term which the authors had adopted. There was one point he would like to refer to in order to show that Dr. Carpenter had taken into consideration certain work done by Professor Roozeboom without making the National Physical Laboratory responsible for that work. He had taken that position most clearly, and, as a matter of fact, the calculations of Roozeboom were based upon the work of only one school of thought; he was supplied with data by the allotropic party, and the work of the carbonist party was never brought under his notice. Therefore his curves were based upon what they (the carbonists) called inaccurate data. He would ask the members to turn to page 238, more particularly to the curve No. 7, with carbon 0.24 per cent., because that percentage was a critical carbon on which to take observations for determining theoretical matters concerning Ar1, Ar2, and Ar3. In that connection, in order to convey a very different impression as to chronographic curves, he would ask Professor Ewing to kindly refer to the *Journal of the Iron and Steel Institute*, 1899, No. I. p. 112, Plate XIII. He had no hesitation in saying that more delicate and accurate curves had never been taken. If one turned to No. 7 one would observe that points Ar2 and Ar3 were confounded, and that the point Ar1 was an exceedingly small point. Whereas in the curve 0.21 per cent. carbon steel, published by Mr. McWilliam and the speaker in their paper on the "Diffusion of Elements in Iron," the points were perfectly distinct, and Ar1 was decidedly the largest point.

They submitted that the curve was due to the well-considered conditions under which it was taken: that Ar2 and Ar3 were really not confounded, and that Ar1 was really a point of very much greater magnitude than the others. They had repeatedly at University College *ad nauseam* explored that particular steel, 0.21 of carbon, and they obtained on the inverse rate curve these effects—they had a break Ar3, 792 (diagram). Going on, instead of Ar2 being confounded, they got a steady fall, and by that method of observation they had been able to do what

no autographic method had done. They had done it repeatedly themselves, and it was confirmed last year by Mr. Thos. Baker, M.Sc., that Ar<sub>2</sub> was a duplex point presenting two maxima—at 732° and 707°. Then came another interval, and Ar<sub>1</sub> appeared at 670°. A student looking at the curves in the present paper would think that practically the whole of the work of Osmond and the speaker was wrong. He submitted that Osmond's and his work represented more truly the changes taking place in a bar of forged steel rolled in the ordinary way. He wished to bring those points particularly forward, so that the students might know that the conclusions put forward by Dr. Carpenter were tentative and not final, and he was pleased to say that he was shortly expecting from Dr. Glazebrook and Dr. Carpenter a visit to the University College of Sheffield, where the speaker's apparatus would be thoroughly inspected by them, and he would be able to give them access to a very large number of unpublished observations which had accumulated for fourteen years, and which he had not had the time to publish. Those would be at their service with the greatest possible pleasure. The object of University College was to co-operate in every way with the National Physical Laboratory, which he thought filled a distinct want in their national life. There was one other point which he would like to ask Dr. Carpenter to deal with in his reply.

Mr. HADFIELD: What manganese was there?

Professor ARNOLD: About 0.05—nearly pure iron. The authors had referred frequently to martensite; might he ask what particular brand of martensite they referred to? Because there were several in the market, and each was said to be genuine all wool martensite. He would like to know to which martensite the authors referred.

Dr. R. T. GLAZEBROOK (National Physical Laboratory, Teddington) said he had nothing to say with reference to the technical points. He could not claim to be a metallurgist, but as head of the laboratory he had taken a very great interest in Dr. Carpenter's work. With regard to one matter, he might perhaps say that

there was probably a slight difference in the aims of the two researches which had been referred to. Professor Arnold had devoted immense care and attention to examining the properties of one brand of ore with a definite amount of carbon in it. The paper under discussion was written rather from the point of view of showing the variations in properties which occurred as the carbon contents were varied. It was quite as conceivable that with different rates of cooling, the points that were indicated so clearly by Professor Arnold as discreet and separate, might be shown by a slightly different method of observation as concurrent. On that point, however, he did not pretend to speak with any authority whatever. One remark of Professor Ewing he would like to refer to. Professor Ewing would, he thought, realise that the difficulty of taking photographic records extending over the very long range of temperature covered by those cooling curves was extremely great, and he believed that Dr. Carpenter and Mr. Keeling found it a distinct advantage in their work to be able to see what was going on while the changes were actually occurring.

He had to thank the meeting very cordially on behalf of the National Physical Laboratory for the way the paper had been received, and he could assure them that if in future they could take part in any researches which would be of interest to the iron and steel industry, they would be most happy to do so.

Mr. R. A. HADFIELD, Member of Council, offered his hearty congratulations to the authors of the very interesting paper. They had been kind enough to say that the research had its origin in a suggestion of his some years ago. He had quite forgotten the fact, but he was glad that it had resulted in such a very valuable paper. They had carried out some investigations of that kind in their own works, and if they had anything of interest he would be glad to add those particulars to the discussion by means of correspondence.

Mr. A. McWILLIAM (Sheffield) said there was one point which struck him, and that was with regard to the method of manufacture of those alloys. It always seemed to him that wherever possible alloys for experiment should be somewhat comparable

with those found in practice. One point that was always insisted upon by Professor Arnold, which was a most important one, was, that when the steel came within the limit of actual practice, it ought to be put through some test such as forging, to see whether it was a real best quality steel or not. Many results had been done, for example, upon the final blown metal, from comparatively pure pig in a basic converter. Ordinary analysis would lead one to believe that this was an extraordinarily pure material, and at the same time it was one of the very worst materials one could attempt to use.

With regard to one of the points which Dr. Glazebrook had mentioned, he thought he had misunderstood Professor Arnold altogether. The steel curve which Professor Arnold had drawn upon the board was one which, owing to its tremendous use in practice, had been done very often indeed, but the range of steels which had been done in University College, Sheffield, was very great also. That one had been done hundreds of times; it was the one which the students did for practice, and so it came under almost weekly determination. With regard to the numbers given, he understood they were only tentative; they were only put forward for discussion, and they would all be tried again. It seemed to him that some of the differences might be due to the method of manufacture of the alloys. There was one particularly which struck him as strange—it was No. 2. Nos. 2 and 4 were made by melting Swedish charcoal irons. The phosphorus content was 0.04; a phosphorus content which would not be accepted by any purchaser of Swedish charcoal iron—the maximum should be 0.02. Of course, that was not going to affect the result perhaps, but it was a point worthy of notice if it could be explained in some way. He thought that every material which was being examined in that way for results which were going to be of use in actual practice, should be put through some test which would indicate that they were suitable for trial. He did not say that the National Physical Laboratory could do that. The samples were easily obtained of extraordinary purity, which would pass suitable tests, and then their melting-points could be determined. With that proviso the final results, results tested over and over again, would be of the utmost value to all, and especially to those who had not the



time to go into the question of very high temperatures and the determination of those higher critical ranges.

Mr. B. F. E. KEELING, in reply, said that there had been three or four questions asked. Professor Ewing had asked whether they took several curves of the same specimen, and what sort of identity they got. Their practice always was to take two curves. First of all one of them took a curve, and then the other took an independent one. In nearly every case it was exceedingly difficult to split the two on the paper; they practically lay over each other within a degree. Professor Ewing asked them why they did not use the autographic method. They had two reasons. The chief reason was the question of sensitivity. He did not think that with any ordinary size of photographic plate they would have been able to fix a certain temperature to that. Mr. McWilliam had criticised the nature of their analysis. He was not aware whether forged iron-carbon alloys supposed to contain nothing else could be obtained. He was rather doubtful if they could all be prepared up to 4.5 carbon. Their object had been simply to mix carbon and iron, and obtain cooling curves and melting-points of alloys.

Dr. CARPENTER, in reply, said that Mr. Keeling had dealt with most of the points. He thought they had made it plain in the paper that it was a purely experimental one. So far as they were concerned there was no theory, and whether Professor Roozeboom's diagram was used as a source of comparison, or any one else's, did not matter. Their results were simply a test of the existing views as to these changes. They had stated in perfectly explicit language (page 239) that they were not committed to an acceptance of Professor Roozeboom's views.

He might supplement one thing with which Mr. Keeling had dealt, viz., the extent to which the personal equation entered into the taking of observations. They were able to test that point by comparing the cooling curve of their alloy No. 1, as obtained by their method, with that of Sir William Roberts-Austen's pure electrolytic iron, as obtained by the autographic method, and the similarity between the curves was so great that it was impossible to distinguish between them.

As regards the abnormal phosphorus content of alloys Nos. 1 and 2, perhaps Mr. Hadfield, who had supplied the Swedish iron used, could throw some light upon this. But it was to be remembered that the quantities of the elements present, other than iron and carbon, in the alloys were so small that their influence on the solidification ranges and the critical ranges was almost certainly less than the experimental errors of the methods used.

Mr. W. WHITWELL, Past-President, proposed that the best thanks of the members should be given to the authors of that most interesting paper, and the resolution was carried.

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### *CORRESPONDENCE.*

Mr. F. OSMOND (Paris) writes to say that he notes with pleasure the interest shown in repeating, extending, and verifying his earlier experiments on critical points in carbon-iron alloys. If the National Physical Laboratory could find no better task, in its initial investigations, than that of traversing again the ground already traversed, and well traversed, by Sir William Roberts-Austen and Professor Stansfield, it must be concluded that the question appealed to its directors as one of fundamental importance, like that of the atomic weight determinations is to chemists. It may be said that this is indeed so, for the most characteristic properties of iron and of its alloys are closely connected with the investigation of these curious points.

When work requiring minute accuracy is carried out, at great cost, and with all the precautions of delicate physical experiment, it would appear necessary that the results should be published in their entirety, with the fullest details, so that all who are interested may profit by them, and be in position to discuss them. It is to be desired that such a publication should be issued. The contribution presented to the Iron and Steel Institute lacks the original documents. It is not sufficient to

be informed that such and such a transformation occurs at such and such a temperature; it is necessary to be able to follow its shape throughout, and to be able to judge of its magnitude. Some curves are certainly given in Fig. 4, but upon too small a scale; and besides, it is *all* the curves that should be given.

The authors have re-discovered, in the majority of their alloys, the small progressive thermal change found at about  $600^{\circ}$  by Roberts-Austen and Stansfield, and indicated by the symbol ArO. The fine curve for electrolytic iron published by the lamented editor of the Alloys Research Committee, seems to conclusively demonstrate that the point ArO is nothing else than the end point of the range Ar2. Is this terminating point of the range Ar2 maintained at constant temperature throughout the whole series of carbon-iron alloys? Mr. Osmond raised this question in the *Metallographist*,\* when commenting upon the experiments of Professors Curie and Morris on the appearance and disappearance of magnetism. For want of sufficient data it was impossible to arrive at definite conclusions; but Mr. Osmond thinks it probable that the Roberts-Austen point, ArO, *i.e.* the point ArO in pure iron, becomes rapidly lowered with increased carbon contents. The four first samples of Dr. Carpenter and Mr. Keeling appear to confirm this view, inasmuch as ArO drops from  $616^{\circ}$  to  $576^{\circ}$  when the carbon rises from 0.01 per cent. to 0.12 per cent. If this interpretation is correct, the point ArO will assume, in more highly carburised alloys, a very different signification. The carbon induces the appearance of the point Ar1, the *recalcescence*; whilst the metal either gives out heat, or maintains itself at constant temperature, the surrounding objects continue to cool, so that, once the period of recalcescence is over, the metal, now in a relatively cool environment, begins to cool at an accelerated rate, which ultimately yields place to the normal rate of cooling. This might be the cause, in alloys containing sufficient carbon, of the point designated ArO, which Mr. Osmond has frequently observed in his own curves without, in view of the foregoing explanation, attaching any importance to it.

In the alloys containing from 0.8 per cent. to 4.5 per cent. of carbon, the point Ar3, which Dr. Carpenter and Mr. Keeling

\* Vol. i. p. 266.

have re-discovered really small, although nearly always present, might well be due to some accidental cause. Steels heated in air (and it would be the same in any other medium) are superficially decarburised, and surround themselves with a skin of variable carbon content. If this is so, and it would be easily proved by micrographic analysis, this slight surface-skin will possess its own distinct critical points, and if the recording apparatus is sufficiently delicate, the presence of an abnormal point,  $Ar_3$ , in eutectoid and hyper-eutectoid steels becomes readily explicable.

Leaving for a moment these two apparently incidental questions, it is stated that the authors have established, by experiment, the existence of the line  $Aa$ , added to Roberts-Austen's diagram by the shrewd intuition of Professor Roozeboom. This is an important fact. It would seem, moreover, that the lines  $SE$  and  $Ea$  merge into one continuous and practically straight single line,  $Sa$ . If this is really so,  $aBC$  is the line of the cementite-iron eutectic, the lines  $EB'$  and  $EF$  disappear, and the final result is that the graphite-iron diagram is no longer represented unless perhaps in alloys containing more than 2 per cent. of carbon, by the points between  $1035^\circ C.$  and  $1090^\circ C.$ , attributed without well understood reasons to an independent separation of cementite, a separation which should start at the moment of solidification. It would be easy to verify this hypothesis by observing the results of quenching, before and after the critical interval noted, by examining the microstructure, and by estimating the graphite. It is to be hoped that these experiments may be carried out. For the moment we appear to be without any authentic information respecting the diagram of the iron-graphite alloy. It intervenes, nevertheless, in metallurgical changes, but the transformations probably, as a regular thing, suffer retardations, often prolonged and often even indefinite, and varying, in addition, with the chemical composition, and with other more or less undetermined conditions.

Mr. JOHN PARRY (Ebbw Vale) writes that some time ago he directed attention to the fact that the fusion point of steel must vary with the percentage of foreign elements present, naturally

attaching most importance to the percentage of carbon. Simultaneously Sir William Roberts - Austen brought forward his views, which practically coincided with his (Mr. Parry's), and which might be summarised as follows, on the assumption that pure iron is practically infusible by ordinary works methods:—

The lower the percentage of carbon, or, perhaps better, the minimum percentage of total foreign elements present, the higher the fusion point. It follows therefore, say for instance, that low carbon steels require to be heated to a sufficiently high temperature to form a plastic material capable of being rolled without danger of being cracked or even broken when passing through the rolls.

On the other hand, a high carbon steel heated to the same temperature might approximate so nearly to its fusion point as to be useless. In other words, such steel would be rotten and useless, although chemical analysis would afford no clue to the discrepancy. These results Mr. Parry has seen in actual practice. He once wrote on the above subject to the *Iron and Coal Trades Review*, dealing fully with the matter of the fusion point, pointing out that (1) the fusion point of any steel, soft or hard, must first be determined. (2) The rolling temperature must be in accord, for the simple reason that a high-fusion steel must be highly heated in accordance, or the metal would be hard, and not sufficiently plastic for passage through rolls with cracking. (3) On the other hand, low-fusion steels, heated to the same temperature as high-fusion metal, will so nearly approximate to the fusion or, perhaps better, the non-plastic stage. Thus high-fusion steel and low-fusion steel will, according to the man in charge, be both equally bad, the sole difference being non-recognition of the fact that the heat required for insuring the plastic condition suitable for rolling is not in accord with the theory previously enunciated.

Dr. T. K. ROSE (London) writes that the curves of equilibrium of the iron-carbon series are sufficiently important to be worth re-determination as often as it may be necessary to insure accurate plotting. The results of the authors may be accepted generally without question, especially as they confirm most of the results obtained by Sir Wm. Roberts-Austen, whose work

has apparently not been carefully studied by Dr. Carpenter and Mr. Keeling. Thus they state in their conclusions that their results confirm, broadly speaking, the accuracy of Roozeboom's diagram (which, by the way, was based on Roberts-Austen's experiments), subject to certain qualifications. Of these Nos. 3, 4, and 5 are merely restatements of Roberts-Austen's views. In the reports to the Alloys Research Committee the lines A B and P K were always represented as rising from A to B and from P to K, and although SE was represented by a curve in the earlier papers it was given as a straight line in Fig. 11 in the James Forrest lecture at the Institution of Civil Engineers in April 1902. The conclusions, Nos. 1 and 2, though possibly correct, need further confirmation, care being taken to prevent the alloys from absorbing either carbon or oxygen during melting. It may be doubted whether a change from the expression "critical point" to "critical range" is entirely a matter for rejoicing. It is convenient to speak of the freezing-point of an alloy, although reference is made only to the beginning of solidification. Very few alloys solidify completely at one temperature, but no obscurity is introduced by speaking of their "freezing points" instead of their "freezing ranges." Perhaps it is as well to introduce as few changes of nomenclature as possible.

Professor BAKHUIS ROOZEBOOM writes that he has seen with the utmost interest the results of the new experiments of Messrs. Carpenter and Keeling on the solidification and transformation of iron-carbon alloys.

He agrees with them that the great many points on the lines AB, Aa, and aB confirm in all its details the representation he had in 1900 given of the solidification of the alloys from 0.43 per cent. carbon. The range of solidification becomes greater from 0 to 2 per cent., and diminishes from 2 to 4.3 per cent., just as should be the case when there are built mixed crystals of martensite with a maximum content of 2 per cent. carbon. This part of his theory is therefore wholly confirmed.

Now the question arises, What is the meaning of the eutectic point B and the eutectic line aBC? Does it represent the building of an eutectic martensite (2 per cent. carbon) + graphite or martensite + cementite?

If the first, then the points found between  $1031^{\circ}$  and  $1090^{\circ}$  could represent, as the authors seem also to think, the commencement of separation of cementite from the martensite with 2 per cent. carbon, which is, after solidification, present in all mixtures with 2 to 4.3 per cent. carbon.

These points were then the line EF indicated before by him as representing the transformation of martensite + graphite into cementite. This idea he has given up after duly considering the discussions on his former paper and the experiments that followed it. He believes they have made it clear that graphite is between  $700^{\circ}$  and  $1000^{\circ}$  more stable than cementite, and thereby the mentioned transformation could not exist.

Nevertheless, the line ES, which is now once more found by the authors, proves that the martensite deposits by cooling much more easily cementite than graphite. The line EF becomes then the commencement of this deposition in the martensite, with the maximum content of 2 per cent. carbon, which is present in all alloys from 2 to 4.3 per cent. The temperature would be near to  $1050^{\circ}$ .

His old line  $\alpha E$  is now no more the separation of graphite from martensite, but the range of existence of martensite with 2 per cent. carbon from the temperature of its solidification to the temperature where it commences to deposit cementite.

The eutectic line  $E'B'$ , for the solidification of the metastable eutectic martensite + cementite, would lie between  $1050^{\circ}$  and  $1130^{\circ}$ . As yet the difference between  $\alpha BC$  and  $E'B'$  has not been settled. New experiments were necessary. Perhaps the small difference might be the cause that the liquid mixtures solidify partly to martensite + graphite and partly to martensite + cementite.

As to the new points at  $800^{\circ}$ , he believes they might represent a transformation of  $\alpha$ -cementite (above  $800^{\circ}$ ) into  $\beta$ -cementite (below  $800^{\circ}$ ). The eutectic point S were then the transformation: martensite 0.9 per cent. carbon into ferrite +  $\beta$ -cementite.

Were this supposition founded, then the maximum evolution of heat at  $800^{\circ}$  ought to be given by the alloy with 6.6 per cent. carbon.

Just the same when the points at  $600^{\circ}$  indicate a transformation of  $\alpha$ -ferrite in, say,  $\delta$ -ferrite, then the maximum should lie at 0 per cent. carbon.

These and other questions could not be settled without the inspection of all the cooling-curves obtained by the authors. Their publication is of the highest necessity.

The greater stability of graphite than cementite, which he has accepted now in agreement with most of the steel authorities, has, however, one strong argument against it, which has not yet been weakened, viz., the possibility of cementation with graphite to a much higher percentage of carbon than is retained in solution at the same temperature when by long heating graphite is separated from the martensite. There remains, therefore, much matter for further inquiry.

Dr. CARPENTER and Mr. KEELING, in reply to the above, remarked that they were much gratified with the kind reception that had been accorded their paper. They noted that in regard to certain points they were criticised from one quarter and commended from another quarter. Accordingly the various communications answered one another to a certain extent.

In reply to the request made by Professors Ewing, Roozeboom, and Osmond for the publication of all the cooling curves, they would state that they had expressed to the Secretary of the Institute their entire willingness to supply every curve. They had been informed, however, that owing to lack of space it was impossible to include them in the forthcoming Journal.

The authors were quite unable to agree with Mr. Osmond's statements in regard to the signification of  $ArO$  "in more highly carburised alloys." Mr. Osmond pointed out that, after a critical change was completed, the alloy cooled rapidly at first, and then gradually approached the normal rate of cooling. But the curve produced would in this case be a smooth curve without points of inflexion. In the authors' experiments in the neighbourhood of  $600^{\circ} C.$  the difference in temperature between the alloy and the platinum cylinder actually increased more or less suddenly, showing an indubitable evolution of heat in the iron.

The explanation by Mr. Osmond of the small thermal change at about  $790^{\circ}$  found for alloys with carbon content 0.8 to 4.5 per cent. was reasonable. The authors noted that he referred to this change as "the point  $Ar3$ ." They apologised for the misconception which had arisen on account of its place in column vi.



In order to economise space a thick line was drawn in columns vi. and vii., below alloy No. 7, to differentiate the high carbon from the low carbon series, and they were careful not to classify the change either as Ar3 or Ar2 in referring to it. Professor Ewing's suggestion that it is reasonable to conclude that the change is Ar2 was one that had occurred to the authors as the most probable, but lack of time prevented their testing this.

With reference to Dr. Rose's criticism that care should have been taken "to prevent the alloys from absorbing either carbon or oxygen during melting," they would point out to him that the alloys were analysed for carbon *after*, not before, manufacture. The range of solidification had been determined, not *in vacuo*, but in an atmosphere in which various gases besides oxygen were present. Hydrogen, nitrogen, argon, &c., had to be taken into account.

In regard to the question of nomenclature raised by Dr. Rose, the authors must prefer a phrase which described a phenomenon accurately to one which did so inaccurately; they dissented strongly from his opinion that although "very few alloys solidify completely at one temperature, no obscurity is introduced by speaking of them as though they did." The range of solidification of alloy No. 23 is 247° C.

#### VOTES OF THANKS.

Mr. W. WHITWELL, Past-President, said they had a duty to perform before they separated, and that was to once more thank the Institution of Civil Engineers for the kindness which they had experienced for so many years by being allowed to meet in their admirable premises. He hardly knew how they could get on without them, and their indebtedness ought to be expressed before they separated. He proposed that their most grateful thanks should be given for the kindness extended to them by the Institution of Civil Engineers.

Sir LOWTHIAN BELL, Past-President, seconded the motion, which was carried unanimously.

Sir BENJAMIN HINGLEY, Vice-President, proposed that their

best thanks be presented to Mr. Carnegie for his conduct in chair.

Mr. G. J. SNELUS, Vice-President, had great pleasure in seconding the resolution, and upon being put to a show of hands was carried unanimously.

The proceedings then terminated.

The following papers were taken as read:—

## TROOSTITE.

By HENRY COOK BOYNTON, S.M. (HARVARD UNIVERSITY).

THIS paper is a result of a number of experiments which have been pursued in the Metallographical Laboratories of Harvard University. It will, I hope, help to clear up a few facts in regard to the identity of a constituent, which, although mentioned by several prominent metallurgists, yet has not apparently been generally accepted or understood by the profession as a whole, if one may judge by the lack of published matter.

It was in 1895 that Osmond first mentioned a new constituent which he had discovered and which he named in honour of the eminent French chemist Troost. In his paper first published in the year mentioned above, but now thoroughly revised and brought up to date,\* he describes troostite as being a constituent which he obtained by quenching during the critical range.

In detail, his method was to heat a piece of 0.45 carbon steel to 825° C., cool slowly to 690°, and then quench in water at the temperature of the surrounding room. On polishing in "bas-relief," three constituents of varying hardness were discerned; by the "polissage-attaque" the hardest areas were found to be martensite, the soft hollows ferrite, and the intermediate component which enveloped the martensite, which was tinted yellow, brown, blue, or black, he named troostite (see Fig. 1).†

The structure of this troostite Osmond describes as nearly amorphous, slightly granular, and "mammilated." He adds that troostite is also found in hard steel quenched during recalcence, but he shows no photograph of it. Mr. Osmond also says that there is no trouble in distinguishing troostite from martensite, and that the former passes very gradually into sorbite.

Other means of preparing troostite consist (1) in tempering a previously quenched piece of steel, (2) in quenching in oil or

\* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, May 1895; *Méthode Générale pour l'Analyse Micrographique des Aciers au Carbone*.

† Reproduced from the *Metallographist*, vol. iv. p. 281, through the kindness of Professor A. Sauveur.

boiling water, or in quenching in cold water a relatively large specimen.

According to Osmond, troostite is also found in steel of 0.14 per cent. carbon quenched between  $A_{r_2}$  and  $A_{r_3}$ ,\* in 1.24 C.† and 1.57 C. steel.‡ To sum up briefly, he believes that quenching during recalescence, or tempering, transforms "progressively hardenite and austenite (the former more rapidly than the latter), first into troostite and then into sorbite."

Being transitional forms, Osmond states that troostite and

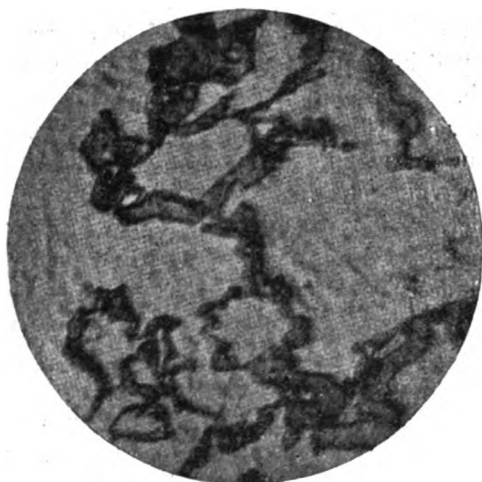


FIG. 1.—Steel containing 0.45 per cent. C. Heated to 730° C. and quenched in water during critical range. Magnified 1000 diameters.

sorbite need no place in Roberts-Austen's and Roozeboom's diagram, which illustrates only definite states of equilibrium.

The only comment that Osmond makes in regard to the composition of troostite is that it "corresponds to some transitory association between Beta iron and carbon."

Following Osmond's paper, practically no new data in regard to troostite was brought forward for some time; Professor A. Sauveur quotes from Osmond's paper§; the late Sir W. C.

\* *Société d'Encouragement*, 1901; *Contribution à l'Etude des Alliages*, p. 306.

† *Ibid.*, p. 317.

‡ *Ibid.*, p. 318.

§ *The Metallgraphist*, vol. i. p. 37.

Roberts-Austen\* mentions it, reproducing a photomicrograph, and describes troostite and sorbite as modifications of cementite.

H. Jüptner von Jönstorff† describes troostite as a "jagged and stringy constituent between martensite and ferrite," and says it "may hold a similar relation to these constituents as sorbite does to ferrite and cementite in pearlite." He adds that "Troostite and sorbite apparently exist only at those temperatures which correspond to the formation of pearlite or to the separation of free cementite, and are retained in the cold metal by sudden cooling from such temperatures."

Osmond, in a later article,‡ tells us how troostite may be recognised by polishing and etching with nitrate of ammonium by its yellowish-brown or blue bands merging into each other; and it is Osmond again who, in vol. iv. of the *Metallographist*,§ notes the presence of troostite in the structure of some steel cylinders, the interiors of which had been superficially hardened by explosions of powder. His photomicrograph || resembles very closely the troostite obtained by me under very different treatment, and which I shall describe later. Osmond used in this case soft steel, and observes that the troostite in his specimen exhibited a new peculiarity, that of "assuming the shape of needles, recalling the structure of martensite."

On account of criticisms, Osmond later defines a little more clearly his conception of the two constituents, troostite and sorbite. In quenching a piece of carburised iron from a high temperature it passes through the following phases: austenite, martensite, troostite, and sorbite, any one of which may be seen in a sample at the ordinary temperature on quenching during its moment of formation; that is, during the different stages of the period of recalescence.

Osmond says at this time: "Troostite represents a transition form which approaches more than martensite the normal state of equilibrium at the ordinary temperature. Micrographically it can be sharply distinguished from martensite as stated above ;

\* *Proceedings of the Institution of Mechanical Engineers*, 1899, p. 35; Report of the Fifth Alloys Research Committee.

† *Metallographist*, vol. ii. pp. 235-236.

‡ *Ibid.*, vol. iii. p. 3.

§ *Ibid.*, vol. iv. p. 23.

|| *Ibid.*, vol. iv. p. 25.

between troostite and sorbite, however, there is no well-defined demarcation. . . . Troostite may be produced either by the sudden cooling of steel during the period of recalescence or by a mild quenching (in oil or boiling water, for instance) of small pieces from a temperature higher than that of the critical range, or, again, by a mild tempering of martensite. Sorbite approaches still more to the condition of stable equilibrium at the ordinary temperature. It might be called unsegregated pearlite. Between it and troostite or sorbite there exists no sharp line of demarcation."\* He adds that although micrographically the three constituents, martensite, troostite, and sorbite, may not be defined as strictly as might be wished, yet they are near enough unlike to demand recognition and to possess different chemical properties.

Professor H. Le Chatelier† also recognises troostite, and says: "The recalescence phenomenon is not, as we have believed it to be, a simple one. It is in fact a succession of two distinct phenomena: the transformation of pearlite into troostite, and followed by the transformation of troostite into martensite. I ascertained this fact in studying the dilation of steel. A steel containing 0.9 per cent. of carbon, on being heated, when it reaches the recalescence point, exhibits a sudden contraction, immediately followed by an expansion of the same magnitude, and amounting to about 0.1 per cent. . . .

"The metal quenched at the beginning of the sudden contraction was found to be made up entirely of pearlite; quenched when the maximum contraction was reached, it was composed almost entirely of troostite surrounding a few particles of pearlite and of martensite; finally, when quenched as soon as it had assumed its normal dimensions, the metal was found to be made up entirely of martensite. . . . I did not obtain any indication concerning the composition of troostite; it is very likely a solid solution, differing from martensite and austenite in being magnetic at its temperature of formation."

Professor A. Sauveur, in the *Metallographist*, gives a brief summary of what has been done in metallography about troostite and sorbite. He goes over the same ground which I have just

\* *Bulletin de la Société d'Encouragement*, 1900, p. 609.

† *Ibid.*, 1900, p. 661.

mentioned, and says, in speaking of troostite and sorbite, that "their existence as structural entities can no longer be contested." He also gives photographs of these two constituents of steel.\*

In the Glossary of metallographical terms† troostite is defined as follows: "This constituent, according to Osmond, is contained in steels of various carbon contents on quenching at certain temperatures. It is revealed by polishing the steel on parchment moistened with a solution of liquorice root or nitrate of ammonia. It readily assumes a brown colour by such treatment. It is relatively softer and more rapidly acted upon by acids than martensite. Its composition and molecular construction has not been determined. This is easily recognisable on etching with hydrochloric acid (1 c.c.) in alcohol (100 c.c.). It colours dark while martensite remains entirely unaffected in colour. By reason of the troostite being softer than the surrounding martensite, it has not hitherto been obtained in tangible form." (Martens and Heyn.)

According to the latest researches on expansive properties by H. Le Chatelier, "this is an intermediate formation which occurs on the transformation of martensite into pearlite, and *vice versa*. It is very likely a solution of the carbide  $C_3Fe_9$  in iron."

Baron Hanns Jüptner von Jonstorff, in his article in the *Metallographist*, remarks: "Of great interest are Le Chatelier's observations on the expansion of steel and the transformation of troostite. The sudden contraction attending the transformation of pearlite into troostite would account for the diminution of volume which so frequently occurs during the formation of solutions. In like manner it would seem reasonable to assume that the equally sudden expansion which accompanies the transformation of troostite into martensite may be accounted for by regarding troostite as a solution of carbide of iron which is decomposed or becomes depolymerised on its transition into the martensite form; the expansion being due to the increase in the number of existing molecules."

Professor H. M. Howe, in an article on "Iron and Steel" in the *Encyclopædia Britannica*, merely mentions the existence of troostite, sorbite, and austenite. In his new book, "Iron, Steel,

\* *The Metallographist*, vol. iv. p. 279.

† *Journal of the Iron and Steel Institute*, 1902, No. I. p. 90.

and other Alloys,"\* he barely alludes to troostite, together with martensite and sorbite, saying that "martensite, troostite, and sorbite are transition forms between austenite on the one hand and ferrite and cementite on the other, probably containing all three of these substances, but in varying proportions."

Professor Sauveur adds: "It would seem, moreover, as if the transformation of martensite (solid solution containing 0.80 per cent. carbon or less) were not an abrupt but a gradual transformation, the martensite passing through some transitive forms, called by Osmond troostite and sorbite, before assuming the final pearlite condition."†

To summarise briefly the data mentioned above, it appears, then, that—

I. Troostite may be defined as an intermediate or transitory form between martensite and pearlite.

II. It may be produced in the cold by—

- (a) The quenching of steel of different carbon contents during the recalescence period—that is, during the time when martensite is undergoing its change to pearlite;
- (b) A mild quenching of small pieces from a temperature above the critical point (in oil or in boiling water, for instance);
- (c) A mild tempering of martensite.

III. The formation of troostite on quenching during the recalescence period is accompanied by a sudden contraction indicating a molecular change in the metal (Le Chatelier and von Jonstorff).

IV. Its composition and properties are doubtful, being given as—

- (a) A modification of cementite (Roberts-Austen);
- (b) A solid solution, differing from martensite and austenite by being magnetic at its temperature of formation (Le Chatelier);
- (c) "Very likely a solution of the carbide  $C_3Fe_9$  in iron" (Glossary);

\* Page 181.

† *The Metallurgist*, vol. iv. p. 255; "The Microstructure of High Carbon Steel."



- (d) Mixtures of austenite, ferrite, and cementite in varying proportions (Howe);
  - (e) Softer than martensite (Osmond).
- V. Its microstructure may be resolved and recognised by—
- (a) Polishing and etching with liquorice root or ammonia nitrate, when it assumes a yellowish-brown colour, or blue bands merging into each other (Osmond);
  - (b) Slight etching with dilute tincture of iodine, when it also assumes brown bands in the shape of needles resembling martensite, but surrounding grains of hardenite (saturated martensite), between the grains there being ferrite (Osmond);
  - (c) Its being a jagged constituent between martensite and cementite (von Jonstorff);
  - (d) Etching with hydrochloric acid (1 c.c.), in alcohol (100 c.c.) (Glossary).

It is my intention in the matter following to present some material which will, I think, confirm positively the existence of troostite, and to add some data which has not hitherto been published.

In the course of a number of experiments performed in the Metallographical Laboratory of Harvard University, under the supervision of Professor Albert Sauveur, it was thought that the following experiment would be instructive, and would give valuable data in regard to the various constituents of steel :—

Two forged bars of 0.54 per cent. carbon steel,  $\frac{1}{2}$  in. square in section and 14 in. long, were heated to 900° C., being placed side by side in a gas muffle furnace; they were then allowed to cool slowly in the furnace—(1) to remove all possible evidence of cold work, and (2) to secure a uniformly coarse crystalline structure throughout the entire length of the bars. Any change of structure could then be easily recognised.

These two bars were then held tightly together, and one end was heated in a forge to a white heat, while the other end of the bars was barely warm. Both bars were withdrawn; one of them immediately quenched in cold water, while the other was allowed to cool slowly in air. By proceeding in this way it is perfectly evident that the results of quenching from any possible temperature, from a white heat down, must be found somewhere

in the bar. By examining the bar from one end to the other we must necessarily find all the constituents which can possibly be retained in the cold by sudden cooling from any possible temperature. These conditions, therefore, must be excellent for the production of troostite, since a certain portion of the bar must necessarily have been quenched during the critical point.

In the slowly cooled bar we should likewise find all the constituents which are formed in steel by reheating to any desired temperature followed by slow cooling.

An examination of these bars from the hot to the cold end ought to give a continuous picture of a very instructive nature, for in it should be displayed the whole history of the transformations alluded to in this paper.

To facilitate microscopic study of the two bars two longitudinal sections from the hot ends of each bar were taken and polished. By taking the first sample 1 inch in length, and the second 2 inches, it was possible to get in the latter section all the visible changes in the structure, from above, down through, and below the critical point of the steel.

A continuous picture was taken of each one of these 2-inch samples, and each showed, as expected, the different changes of structure from above and down through the critical point.

The unhardened piece—that is, the one allowed to cool in air—was etched with strong nitric acid (sp. gr. 1.42) and ruled with a fine hardened needle as shown in Fig. 2.

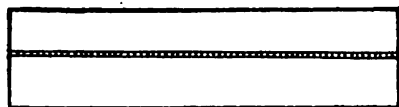


FIG. 2.

The two longitudinal lines and the cross lines were drawn  $\frac{1}{32}$  of an inch apart, making a number of squares  $\frac{1}{32}$  of an inch on a side. A picture of each one of these squares was taken on a separate plate, and the prints were cut along the ruled lines, pieced together in order, and mounted on a long cardboard, forming a continuous picture showing all the changes in structure.

It was found difficult to rule the hardened piece by the above method, so that I devised a better plan of marking (Fig. 3).

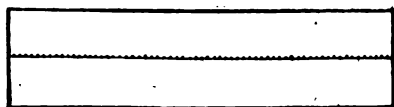


FIG. 3.

One longitudinal line was drawn through the centre the whole length of the specimen, and it served as a base line upon which dots were made to locate each photograph. By keeping the base line and dots at one edge of each plate a continuous picture was taken, which, when the different sections were matched together, was perfectly continuous with no divisional line from end to end; it was, therefore, possible to match perfectly a part of a grain occurring on the divisional part of one plate to its other part on the neighbouring section.

A number of interesting facts were brought out by these continuous pictures. The original structure of the bars previous to any treatment is given in Fig. 4. It shows a moderately

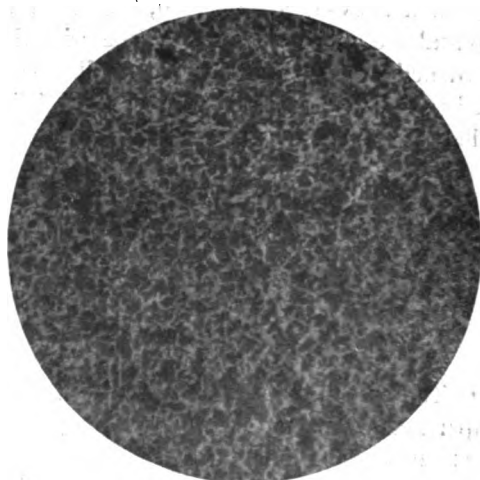


FIG. 4.—Original Structure. Magnified 1000 diameters.

fine structure of the network variety, showing that the bar was forged down to near the critical point, and then allowed to cool

in the air, the dark constituent being pearlite and sorbite, and the light, ferrite. On heating the two bars to  $900^{\circ}\text{C}$ . and cooling in the furnace nothing new was produced in the line of microstructure (see Fig. 5). Here, however, the network structure has practically all disappeared, being replaced by a coarse structure which, for want of a better name, might be called granitic or granitoid, the dark constituent in this case being all true pearlite, and showing under high magnification the lamellar condition of the eutectic alloy (see Fig. 6).

After heating in the forge as described above, a number of very interesting changes were found to have taken place.

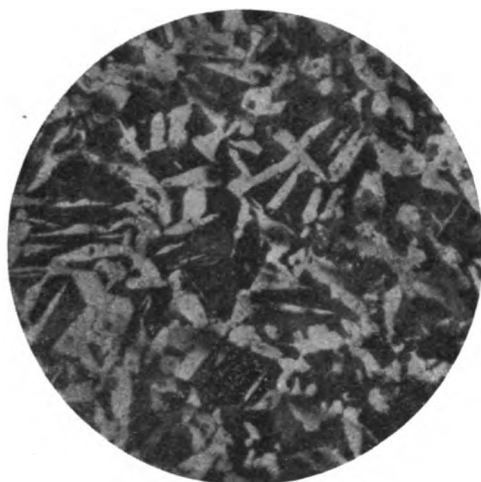


FIG. 5.—Heated to  $900^{\circ}\text{C}$ ; cooled in furnace.  
Magnified 100 diameters.

Taking up the unhardened piece which was allowed to cool in air from a white heat, on the extreme hot end of the bar a coarse network structure was produced (Fig. 7) which changed very little until near the critical point, which by a number of experiments has been found to be (on cooling)  $680^{\circ}\text{C}$ .

The changes in structure at the critical point could be seen by the naked eye as shown diagrammatically in Fig. 8.

At the dotted line CP a very sudden and marked change took place, the network structure immediately became the granitic although extremely fine (see Fig. 9).

This very fine structure, which is made up of true pearlite and ferrite in very small grains, is the "refined structure" desired in

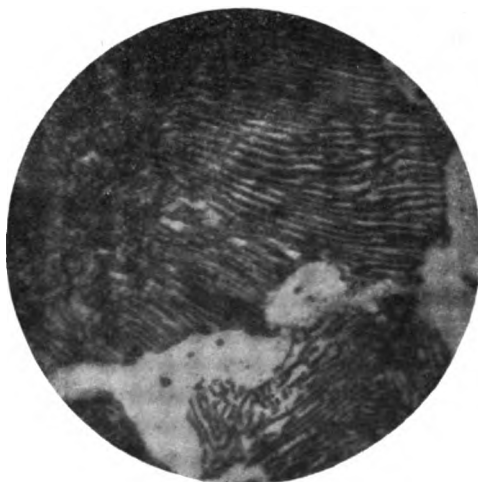


FIG. 6.—Same as Fig. 5, but magnified 1000 diameters.

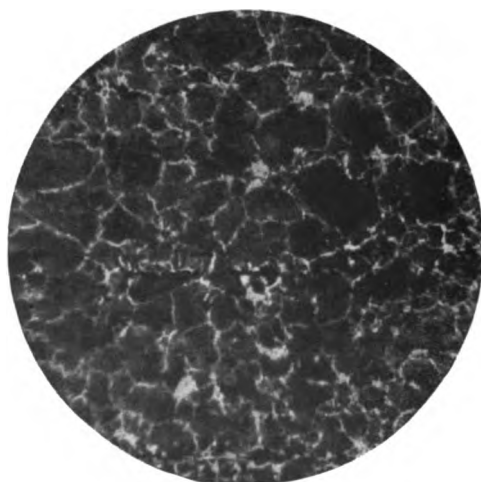
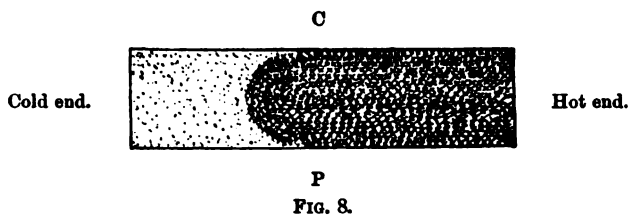


FIG. 7.—Heated to white heat ; cooled in air.  
Magnified 100 diameters.

annealing ; on proceeding toward the cold end, however, this fine structure very gradually became coarser and coarser until

in the actual distance of about an inch from the critical point line, CP, the original coarse structure exhibited in Fig. 5 was attained and continued to the cold end of the bar.

This part of the experiment is simply another instance of the refining of a previously coarse structure by heating to a little



above the critical point. So far nothing new has been presented which is not familiar to the average metallographist; the method, however, of obtaining these results and the continuous picture,

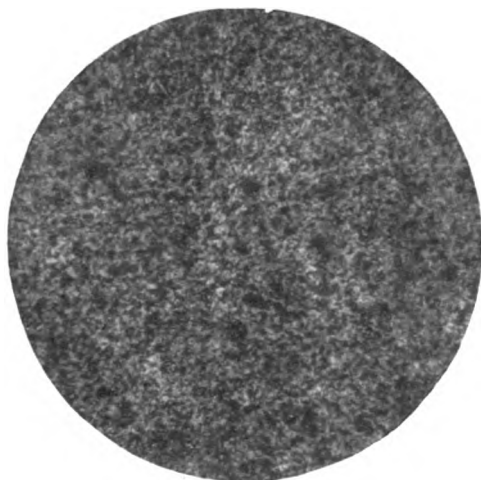


FIG. 9.—Refined structure. Magnified 100 diameters.

which on account of space (the whole series being over 6 feet long) cannot be reproduced here, has never to my knowledge been brought forward.

The quenched sample is more instructive, and has, I believe, yielded results well worth recording. A number of methods of  
1904.—i. S

etching this hardened piece were tried, but the one that seemed to give the best results was a very dilute tincture of iodine, only a very slight application being required.

For about an inch from the hot end of the piece, the only constituent visible was martensite, but from thence a new component was apparent; it appeared brown to black on slight etching and seemed partially to surround areas of martensite (see Fig. 10). A deeper etching required to bring out the needles of martensite would efface it almost entirely. This new constituent on examination with a low power shows nothing

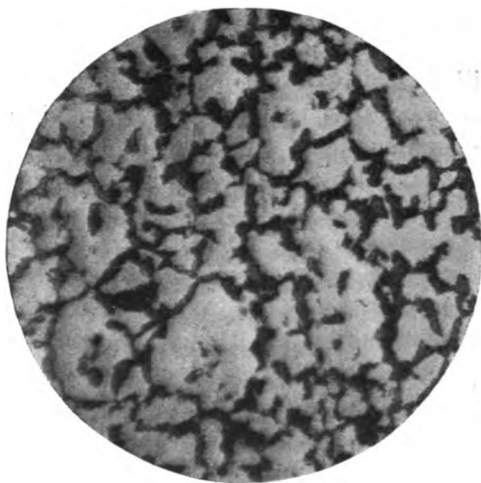


FIG. 10.—Troostite and Martensite. Magnified 100 diameters.

except a sort of jagged network about the martensite; it appears in the section quite suddenly, but at first in a very small amount, which, however, gradually increases on going toward the cold end. This dark constituent is undoubtedly Osmond's troostite. A higher power (Fig. 11) shows the structure of the troostite a little more plainly, and Fig. 12 is the highest magnification that I was able to obtain. The troostite here seems to present a pebbly appearance, or looks like a mass of irregular dots or globules which Osmond has called "mammlated." That the troostite is softer than the martensite can be easily proved by scratching with a hardened

needle; for on ruling the specimen as described above, apparently no impression was made on the latter but a good scratch on the former.

The structure seen in Fig. 10 extends for a space of about an inch of actual distance on the longitudinal section; it varies only a little, but on approaching the cold end the martensite areas gradually decrease somewhat, the troostite proportionally increasing until the latter entirely surrounds almost every grain of the former. The troostite is not, however, entirely confined to the surrounding areas, particles being frequently seen within the martensite grains (Fig. 11).

A continuous photograph was taken and submitted, a few

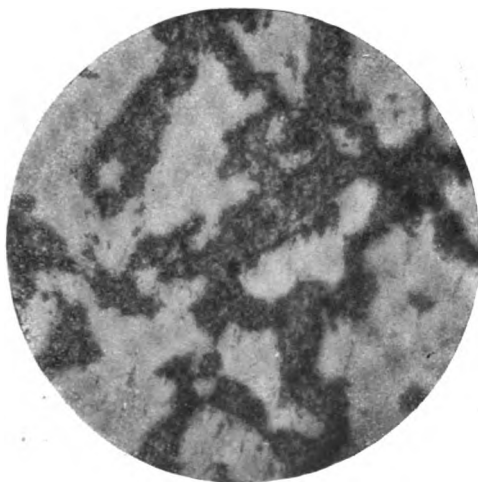


FIG. 11.—Troostite and Martensite. Magnified 250 diameters.

sections of which showed the greater part of the changes near the critical point. The first half of this plate showed the troostite at its maximum development, surrounding the martensite which is here hardenite. In the latter half of the picture, towards the cold end, first appeared a few grains of pearlite; the troostite had not disappeared, and there was still plenty of martensite standing sharply in relief. The pearlite was represented by the dark areas increasing in number toward the right half of the picture, which was toward the cold end of the bar



Fig. 13 shows one of these pearlitic areas under a magnification of 1000 diameters. The two white areas are martensite; the greyish-white or half-tone surrounding them troostite, and the pearlite is about in the middle of the plate. A portion only of this dark area is true pearlite, the balance being sorbite. The picture is interesting, for here may be found martensite, troostite, sorbite, and pearlite, all the constituents which have a bearing in the discussion, present in one photograph. The martensite in Fig. 13 must, at this stage, be of necessity of the variety

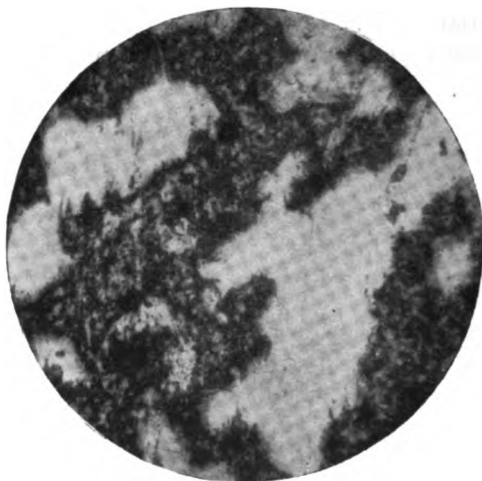


FIG. 12.—Troostite and Martensite. Magnified 500 diameters.

hardened; that is, saturated with carbon, containing about 0.80 per cent. of that element.

The extreme cold end of the bar in the continuous photograph shows almost all of the hardened breaking up into pearlite or sorbite, and the troostite seems to change, but more slowly, into ferrite. Fig. 14 shows a spot of hardened nearly all transformed to pearlite; no ferrite is apparent in the picture, but the troostite which takes its place is visible and surrounds a large mass of pearlite.

A little farther toward the cold end of the bar ferrite appears and rapidly increases in quantity until the original structure of the bar is reached, consisting of about one-half ferrite and the rest pearlite (see Fig. 15).

Turning now to the nature of troostite, I do not find in the results of these experiments evidences supporting Mr. Osmond's

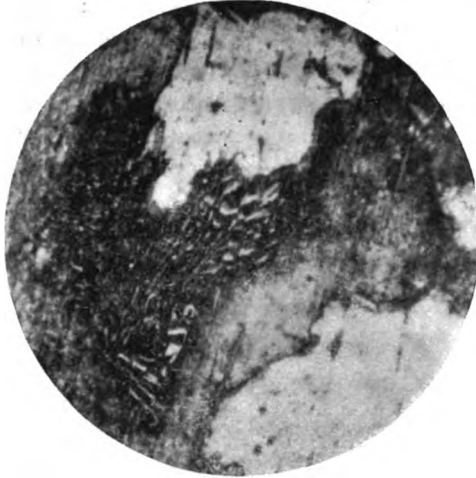


FIG. 13.—Martensite, Troostite, Sorbite and [Pearlite].  
1000 diameters.



FIG. 14.—[Martensite], Troostite, Sorbite, and Pearlite.  
1000 diameters.

contention that this constituent is a transition form between martensite and sorbite. On the contrary, I am led to take quite a different view of the nature and character of troostite.

When a piece of steel such as I have used in these experiments is allowed to cool from a high temperature, at a certain time it is composed exclusively of martensite: all the iron and all the carbon present in the steel have united to form this constituent. On further cooling, the martensite gradually rejects some of the iron (ferrite), its carbon content increasing correspondingly until it reaches approximately 0.80 per cent. The martensite is then said to have reached the condition of hardenite. It is now saturated with carbon; that is to say, upon further cooling it ceases to reject any more ferrite but

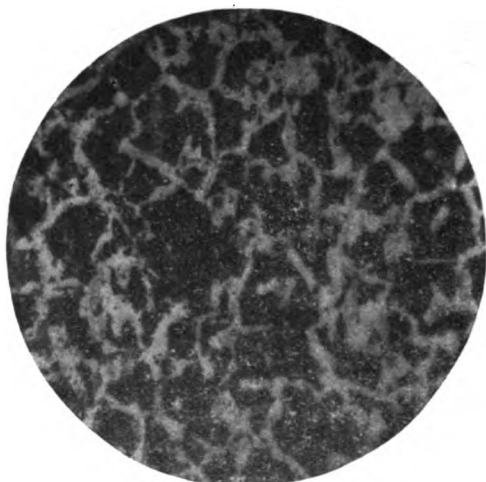


FIG. 15.—Structure below critical point. Magnified 100 diameters.

passes to the pearlite condition. In a steel containing about 0.45 per cent. of carbon, hardenite should occupy about one-half of the total area, the other half being occupied by carbonless iron (ferrite).

If now we refer to Fig. 10, we find that the martensite (the white constituent) occupies but a little more than the total area; it has almost reached the hardenite condition, having rejected considerable iron previously included in the martensite. Must not the constituent making up the balance of the field be carbonless iron? Can it be anything else? Is not troostite then the iron first rejected by martensite during the concentra-

tion period through which rejection it is eventually converted into hardenite? If it is not this iron, where then is the iron rejected by the martensite? What then is the nature of the martensite seen in Fig. 10?

If troostite is a transition form between hardenite and pearlite, it must of course be saturated with carbon; that is, it must contain some 0.80 per cent. of that element. In that case the light areas in Fig. 10, which we have naturally considered as martensite, can contain but a slight amount of carbon. Shall we say 0.10 per cent.? This martensite, if the name could still be applied to it, should be soft, and in fact the steel itself should not be very hard, while the truth of the matter is, both the light constituent and the steel are *very* hard. If this white component which all metallographists have always considered as martensite, in which the carbon is being concentrated by the rejection of iron, finally reaching the condition of hardenite, is instead a slightly carburised iron, undergoing still further decarburisation, what then is hardenite, and under what possible conditions can this constituent exist? If troostite is a transitory constituent between martensite (or hardenite) and pearlite, then our conception of the nature of martensite, of the mechanisms of the structural changes, of the nature of hardened steel itself, in order to fall in line with this assumption, appears to be inaccurate and calls for revision. Every metallographist will admit that the structure shown in Fig. 10 is a normal structure, which can readily be obtained by using proper precautions. Can it be explained in the light of our present conception of the nature of martensite and troostite?

It seems to me that we have here strong evidence that troostite is some form of carbonless iron. It cannot, however, be alpha ferrite; that is, iron as we find it below the critical point. But is it not beta iron? The mechanism of the formation of troostite would be in accord with our understanding of the allotropic transformation of iron: martensite on cooling rejects beta iron (troostite), which during the retardation passes to the alpha condition (ferrite), while the saturated martensite (hardenite) is converted first into sorbite and then into pearlite. I find further support for these conclusions in a close examination of the appended photographs (see Figs. 13 and 14), where many

indications are found of the passage of hardenite to sorbite and pearlite, and of the troostite into ferrite.

This beta ferrite or troostite is coloured dark when first seen, but when viewed with a high power just before its critical change to alpha ferrite takes place, it will be seen to consist of a white or nearly white mass of irregular grains (see Figs. 11 and 12). This different coloration on etching with tincture of iodine may bear out the supposition that the beta ferrite or troostite being in a different molecular state in its arrangement of atoms, might easily be coloured differently from the alpha ferrite, the latter not being acted upon at all owing to the very short etching, and remaining bright.

Whether or not troostite is a form of carbonless iron does not, however, call for much speculation, for the theory presented here can readily be proved or disproved. If troostite is, as I am led to believe, some form of carbonless iron, then this constituent should not be formed in an oversaturated steel, since there is then no excess of iron to be expelled by the martensite, no free ferrite in the slowly cooled metal. A piece of 1.11 carbon steel was, therefore, taken and treated as before; that is, heated to  $900^{\circ}\text{C}$ .; allowed to cool slowly in the furnace, and, when cold, one end heated to a white heat in a forge and quenched, the other end of the bar remaining entirely unacted upon. The results confirmed my reasoning, and may be seen in the photographs.

Fig. 16 shows the original structure of the sample before quenching. All the succeeding pictures are from one longitudinal piece about 2 inches in length, which not only shows all the changes in structure through the critical point, but all the common constituents of an ordinary carbon steel. From the hot end through the centre to the cold end of the piece the following structures are respectively seen: Austenite and martensite; pure martensite; cementite and martensite; cementite, martensite, and pearlite (small amount); cementite, pearlite, and martensite (small amount); cementite and pearlite. On the edges, where a slight decarburisation has taken place, may be seen, in addition to the above, free ferrite and troostite. Also, in a great many places near the critical point, pearlite is replaced by sorbite.

The structural changes which took place were as follows:

Being a supersaturated steel and small in section, the quenching in ordinary water was sufficiently rapid to produce at the hot end austenite which may be seen in Fig. 17, and in Fig. 18 at a higher magnification; on going toward the cold end this austenite soon gives way to the ordinary needle-like martensite which is so familiar to all the profession as not to need reproduction here. On nearing the critical point, however, the solid solution of martensite having more carbon than it can carry, throws off part of it in the form of cementite (see Fig. 19); here the martensite has attained the form of hardenite, and the whole structure exactly simulates the original structure seen in

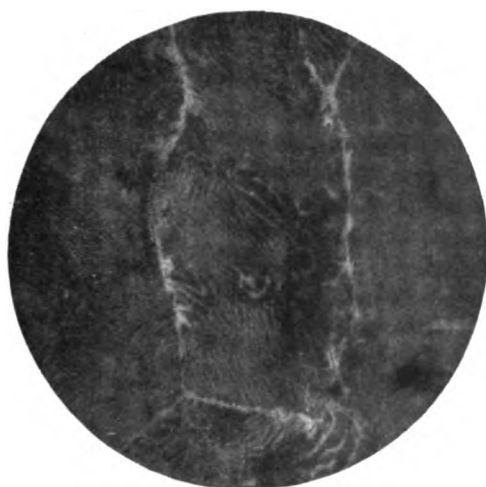


FIG. 16.—Original Structure 1.11 per cent. Carbon Steel.  
Magnified 250 diameters.

Fig. 16, with the exception that the pearlite is replaced by hardenite, being surrounded or contained within the meshes of a network of cementite. On approaching still nearer the critical point the network of cementite persists; the hardenite is, however, dotted here and there with little dark areas made up of pearlite or sorbite (see Fig. 20). This structure is followed by an almost complete change of the hardenite to pearlite and sorbite, with little dots and small white areas of hardenite as islands in the pearlite. The network of cementite does not change in the least. Fig. 21, which is a low-power picture,

shows the little islands of hardenite very plainly, and Fig. 22 shows some of the same spots under a higher magnification,

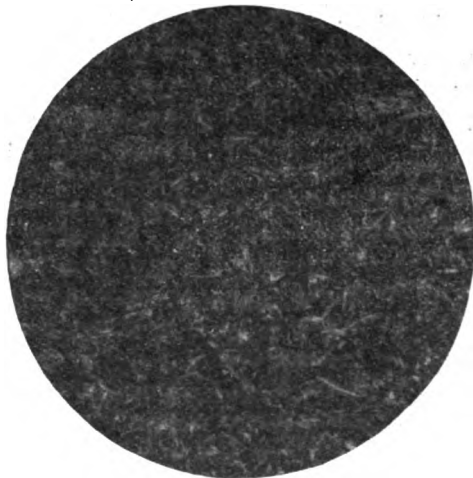


FIG. 17.—Martensite and [Austenite?]. Magnified 100 diameters.

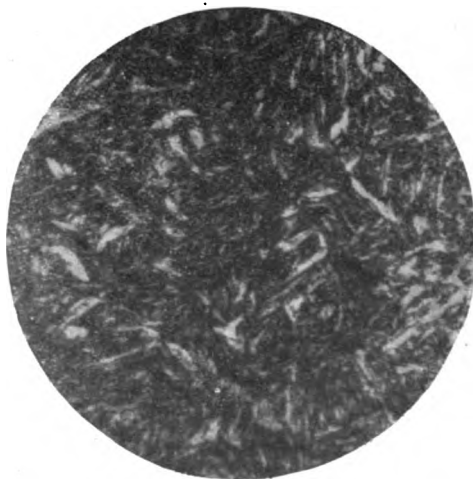


FIG. 18 —Martensite and [Austenite?]. Magnified 500 diameters.

exhibiting the hardenite fading away or seeming to be dissolved in the surrounding pearlite or sorbite. The next change in structure is seen in the complete loss of these small outliers of

hardenite and the recurrence of the same familiar structure of any hypereutectic steel; that is, of pearlite and cementite, with

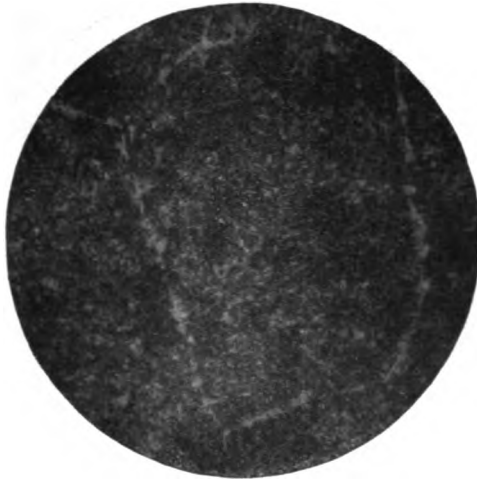


FIG. 19.—Cementite network about Martensite.  
Magnified 500 diameters.



FIG 20.—Hardenite and [Pearlite]. Magnified 500 diameters.

more and more of the former assuming its true or lamellar condition, accompanied by a decreasing amount of sorbite.



Is not the absence of troostite in a supersaturated steel—that is, a steel free from ferrite—a most conclusive proof of the correct-

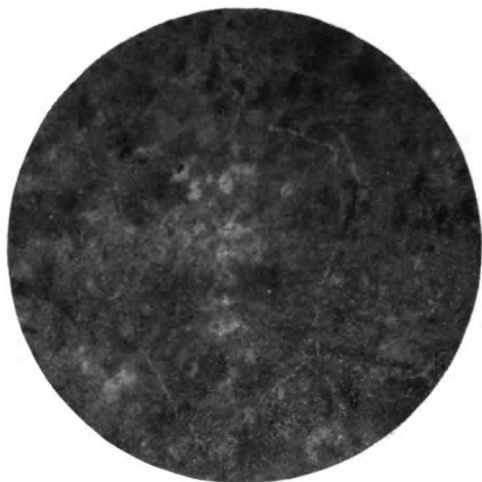


FIG. 21.—Spots of Hardenite in Pearlite.  
Magnified 100 diameters.

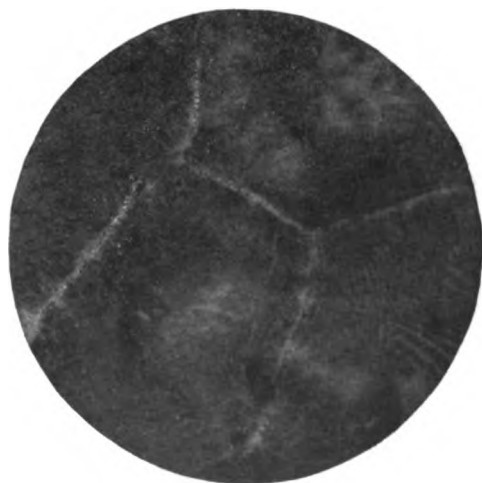


FIG. 22.—Same as Fig. 21, but magnified 500 diameters.

ness of my views concerning the nature of troostite? If troostite be a transition form between martensite and pearlite, it should

be found in greater abundance in a high carbon steel, because of the greater bulk of hardenite which passes to pearlite.

I am well aware that Osmond and Le Chatelier have stated that troostite may be found in oversaturated steel, but they have not shown any photographs in support of this contention; and from the considerations just presented I naturally infer that in those high carbon steels which they have examined they have mistaken sorbite for troostite.

To illustrate further the conclusions I have drawn from the experiments I have presented, the diagrams in Figs. 23 to 25 may be helpful. Fig. 23 represents the change in structure

*Changes in Structure of a Slowly Cooled 0.45 Carbon Steel.*

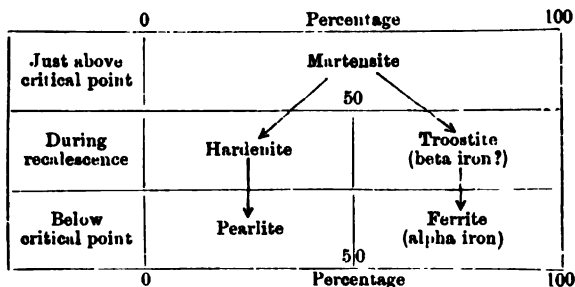


FIG. 23.

which would occur in a piece of 0.45 carbon steel cooled slowly. The structure above the point of recalescence would be composed entirely of martensite (100 per cent.), and can be preserved by quenching at that temperature. During the recalescence, since we have an undersaturated steel, the excess of pure iron or troostite would separate out, and at the end of the period, if this structure be preserved, there ought to be 50 per cent. of saturated martensite (hardenite) and 50 per cent. of carbonless iron (troostite); below the critical point the hardenite has been converted into pearlite and the troostite to alpha ferrite in the same proportion.

With a steel cooled more rapidly we have a slightly different state of affairs; the constituents remain the same, but there is an additional step which must be considered: that of the change hardenite to sorbite, and of sorbite to pearlite (see Fig. 24).

Fig. 24 is necessary because in a great many forms of steel having a relatively small cross section (steel rails, for example) only a very small amount of true pearlite is found, its place being occupied by sorbite. The reason for the large amount of sorbite formed is because pearlite requires some time for the alternate arrangement of its plates of ferrite and cementite, therefore although above the critical point martensite is found, on a rapid cooling through the period of recalescence, time is denied the martensite to throw off all the carbonless iron it could do if the cooling were slower, and so if the structure found there be made permanent by quenching, more than 50 per cent. of martensite would be found, and consequently less than that amount of troostite. No true hardenite could be

*Changes in Structure of a 0.45 Carbon Steel more Rapidly Cooled than in Fig. 23.*

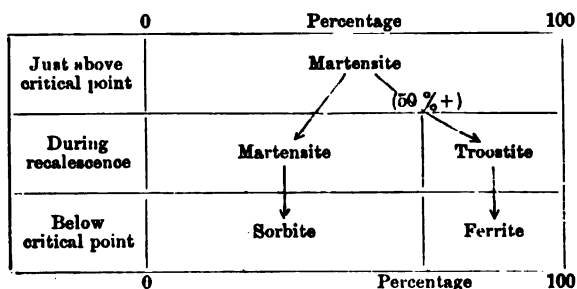


FIG. 24.

present, since there would still be an excess of iron over the eutectic ratio (0.80 per cent.), and on further cooling this martensite with an excess of iron would form sorbite, which has been defined as a "ferrous pearlite," and the troostite would as before become alpha ferrite.

In the case of a supersaturated steel cooled slowly the results are parallel with the slowly cooled undersaturated steel illustrated below (see Fig. 25). Above the critical point, 900° C., for example, martensite is present containing the total carbon dissolved within it; on cooling through the critical point since there is an excess of carbon over 0.80 per cent., this excess carbon unites with some of the iron, and is discarded by the

martensite exactly as troostite was discarded in an under-saturated steel. Since there is no free carbonless iron available no troostite or free ferrite can be present, and below the recalcence period the cementite persists, but the hardenite as before changes to pearlite.

On rapid cooling, as the cooling of small samples in the air, the martensite should contain more cementite than is necessary to form hardenite, and the structure would vary accordingly. Such a structure ought to possess a higher tensile strength and elastic limit over ordinary pearlitic steel as in the case of "sorbitic steel" over ordinary steel. This latter inference has,

*Changes in Structure of a Slowly Cooled 1.20 per Cent. Carbon Steel.*

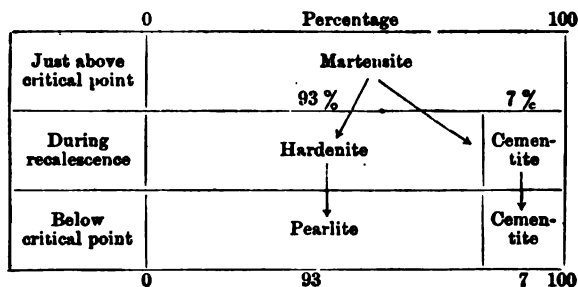


FIG. 25.

moreover, been verified, and the results will soon be published in a following paper.

It is with some reluctance that I oppose the views of such distinguished and able metallographists as Messrs. Osmond and Le Chatelier, and I hope that if I have erred in my reasoning, criticisms of this paper will promptly bring it out. In order to disprove the theory advanced, however, it will be necessary to offer satisfactory explanations of some of the points mentioned in this paper, and which, as far as I can see, can only be accounted for on the assumption that troostite is the form first assumed by the carbonless iron rejected by martensite, and which by slow cooling would be converted into ordinary alpha ferrite.

*CORRESPONDENCE.*

Mr. F. OSMOND (Paris) said that he had read Mr. Boynton's paper with interest, and was in complete accord with the author as to all the facts observed. It is not surprising that these facts may bear varying interpretations. While the problem relating to conditions of equilibrium in solids can, as yet, hardly be regarded as solved, that of the transitional states occurring amidst these conditions of equilibrium can scarcely be said to have been attempted. Indeed, in the present state of our knowledge, it seems very hard.

If an eutectoid steel be quenched during recalescence, and its micro-structure subsequently examined, it will be found to consist partly of grains of hardenite, partly of grains of true pearlite; the remainder consists of transitional constituents sharply distinguishable from hardenite, and passing gradually into pearlite. This transitional area is all that need be discussed here. If the preparation be submitted to polish attack by, for example, ammonium nitrate, and the stages of the reaction be attentively followed, it will be found that in the immediate vicinity of the grains of pearlite the staining takes place with greater rapidity than in the vicinity of the grains of hardenite, that it is more uniform and, in all probability, that the hardness is less. As the result of these observations Mr. Osmond regards this undefined area as consisting of troostite, which is changing gradually to sorbite, and finally to pearlite. Mr. Boynton, on the other hand, regards the whole of this transitional area as consisting of sorbite.

If a bar of eutectoid steel, heated to a temperature above that of recalescence, be quenched in oil or in warm water, it will be found, provided that the sectional area be not too small, that only the surface consists of hardenite. The bulk of the mass presents micrographic characters closely resembling those of troostite or of sorbite. Mr. Osmond regards this constituent as troostite, because of its hardness, which, although considerable, does not equal that of hardenite. Mr. Boynton believes the constituent in question to be sorbite.

Up to this point the divergence of opinion is really nothing

more than a question of definitions. The difficulty actually met with appears to be in deciding whether the constituent obtained, on mildly quenching an eutectoid steel, is identical with that which enfolds the martensite in a hypo-eutectoid steel quenched, at the critical point, in cold water. There is no question, be it understood, as to the *quantitative* identity: it has never been supposed that the troostite of hypo-eutectoid steels is necessarily saturated with carbon, and that it undergoes as a whole and *in situ*, transformation, first into sorbite and subsequently into pearlite, but in any case into sorbite and ferrite.

But while it may be true that the question of the quantitative identity of the troostite occurring in an eutectoid steel mildly quenched, with that of an hypo-eutectoid steel, quenched from the critical point, is not in question, it is none the less true that even the simple *qualitative* identity of the two has not been conclusively established.

It would at least be necessary to prove that the second modification of troostite contained carbon. M. Osmond considers the presence of carbon as probable, firstly, because the ease with which all the reagents act upon it lends support to the view that it possesses ultra microscopic heterogeneity; and secondly, because, according to Mr. Boynton's hypothesis, the troostite of hypo-eutectoid steels, quenched at their critical points, ought to increase in inverse ratio to their total carbon contents, a view which is in contradiction to experience. It must, however, be admitted that these arguments are not conclusive. The diagram of Roozeboom would rather favour Mr. Boynton's views, if one can legitimately invoke it in regard to the study of transitional forms not foreseen by its author. It would therefore appear difficult to arrive at once at a complete and safe definition of troostite, and, provisionally, it would be better, perhaps, to make a distinction between the constituent obtained on mildly quenching an eutectoid steel, and that which is obtained by suddenly quenching an hyper-eutectoid steel at the critical point. However this may be, Mr. Boynton's work remains an interesting contribution to the study of this subtle problem. If it is no longer probable that troostite is  $\beta$ -iron, it is very likely that  $\beta$ -iron, possibly as the result of its still unknown relations to carbon, plays a preponderating part in its genesis.

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Professor LE CHATELIER (Paris) considers the studies pursued by Mr. Boynton very interesting, as systematic investigations of this nature are indispensable to the progress of our knowledge of the different constituents of steel. At the same time he cannot help joining issue with the author, whose proofs as to the absence of carbon in troostite he cannot regard as altogether conclusive. It is true that in the hypo-eutectic steels troostite is often present in the form of a bordering, separating the pearlite or the martensite from the ferrite, but in certain cases the whole of the carburised nodules are transformed into troostite, so that the steel would enclose nothing but pure iron if troostite was but a form of ferrite. Professor Arnold had kindly sent him (Professor Le Chatelier) a sample of steel containing 0.2 per cent. of carbon, quenched at the recalescent point, in which he had been unable to find anything but ferrite and troostite. The statement as to the new existence of troostite in the eutectoid steels and the hypo-eutectoid steels is entirely contrary to experience. By quenching an 0.9 carbon steel at the centre point of recalescence, he (Professor Le Chatelier) had obtained a metal formed of at least 75 per cent. of troostite, of which he had given a photograph on the occasion of the discussion of Professor Arnold's paper. He had also obtained troostite on quenching steels containing 1.7 per cent. of carbon, at recalescence. Mr. Boynton had baptized this troostite by the name of sorbite, but the name had nothing to do with facts. By quenching, during full recalescence, steels from 0.2 per cent. to 1.6 per cent. of carbon, a constituent was obtained, presenting in every case the same micrographical characters. There was, therefore, no reason for supposing them to differ. Justification for such a view could only arise when the experimental facts should have established such a distinction, and he was not aware of the existence of any such facts.

## THE SYNTHESIS OF BESSEMER STEEL.

By F. J. R. CARULLA, F.C.S., DERBY (MANAGER, IN 1874-76, OF THE BESSEMER DEPARTMENT, JOHN BROWN & CO., LTD., SHEFFIELD).

NOTHING is calculated to cause more astonishment to the thinking metallurgist than the success with which the Siemens process of making steel appears to have waged its slow but relentless contest for the mastery over that of Bessemer. For many years the open-hearth process with its deliberate methods seemed destined to permanently keep that place in the manufacture of special steels which was admiringly accorded to it by the makers of the commoner sorts with the converter. Little did they suppose, however, that the rapid operations of the pneumatic process could for cheap material be ever superseded by those of its slower rival. How petrified with amazement such steel-makers must have been if they read the press report of the May meeting of this Institute in 1900 containing the following lines:—

“It was generally agreed, as put by Sir Lowthian Bell, that the Bessemer process would have to be abandoned, and the open-hearth mode of producing steel substituted for it. Sir Lowthian said, as a member of the Steel Rails Committee, he believed that until they were able to make steel rails by a slower and more manageable process than that of Bessemer they would fail in satisfying present-day requirements.”\*

Could the indictment be more serious, or the condemnation more complete? It is not for the better class of steels that the Bessemer process must be altogether put aside, but actually for rail steel! And this barely two years after the death of Sir Henry Bessemer. Surely the process has something intrinsically worthy of permanence that is independent of the presence of its guiding spirit.†

Is this surprising position explainable by the exhaustion in some places of the better class of ores suitable for making

\* *Sheffield Telegraph*, May 10, 1900.

† The fable of the Tortoise and the Hare would once more seem to be on the point of realisation, and this time on the highest scale. Certainly one can suppose that a well-planned melting shop with a goodly number of 200-ton open-hearth furnaces would oblige a couple of even 25-ton Bessemer converters to be kept nimbly on the go, not to be left behind in the output.



Bessemer pig for the acid process, and the consequent necessity to resort to the basic Bessemer more and more? Or, has the condition of affairs complained of been brought about by record-breaking production at a forced pace that makes proper examination of the material before use impossible? \*

That a grievance does exist is very clear, for Sir Lowthian Bell has expressed an adverse opinion of Bessemer rails on more than one occasion. † And yet it is inconceivable that he can bring the acid process under this ban, for so long ago as in 1874 steel rails were being made at the Atlas Works of a quality so uniform as to leave nothing to be desired. That modern requirements could not be equally well fulfilled with the same regularity is a thing that the present writer cannot admit, from the considerations that follow.

#### THE PROCESS. ‡

It is unnecessary to describe the Bessemer process, but it may be useful to have a clear insight of what goes on within the converter, as disclosed by analyses made in 1873.

TABLE I.—*Analyses of a Series of Samples showing the Changes undergone by Pig Iron during its Conversion by the Bessemer Process.*

	Mn.	Graphite.	C. Carbon	Si.	S.	P.
No. 1. The pig iron as it ran from cupola . . .	...	2.62	0.54	2.399	...	...
No. 2. The same, after blowing 1 minute so as to completely mix . . .	0.324	2.72	0.64	2.426	0.117	0.044
No. 3. Taken after 11 minutes' blowing . . .	...	none	2.26	1.285	...	...
No. 4. Taken after 21 minutes' blowing . . .	...	none	1.14	0.69	...	...
No. 5. Taken at the end, after 28 minutes' blowing	trace	none	none	0.065	0.127	0.052
No. 6. Steel after adding spiegel . . . . .	0.649	none	0.36	0.177	0.119	0.055

\* Record-breaking, however, is no new thing. The performance at the Edgar-Thompson steelworks reported in 1889 is an illustration. They received an order for 1000 tons of steel rails from the Pennsylvania R. R. Co., required with urgency, and in 36 hours the whole thousand tons were manufactured and delivered.

† See *Journal of the Iron and Steel Institute*, 1900, No. I. pp. 67-68; also 1902, No. I. p. 146.

‡ The author takes this early opportunity of thanking Mr. J. D. Ellis for permission to make use of much information obtained whilst in the service of John Brown & Co., Ltd.

It is important to note how rapidly the graphite in the pig iron becomes converted into combined carbon as the blowing proceeds and the temperature rises. No analysis of the spiegel used in the above case is available, but the effect of the high temperature of the decarburised iron or blown metal on the spiegel can be seen from the following series of analyses.

TABLE II.—*Analyses of Three Heats.*

No. of Blow.	Material.	Mn.	Graphite.	C. Carbon.	Si.	S.	P.
792	Blown metal . .	0.36	none	none	0.065	...	...
	Spiegel . . . .	13.47	1.22	3.08	1.83	...	...
	Steel . . . . .	1.04	none	0.30	0.066	...	...
793	Blown metal . .	0.058	...	none	0.149	...	...
	Spiegel . . . .	19.30	0.46	3.86	1.34	...	...
	Steel . . . . .	1.08	none	0.29	0.061	...	...
794	Blown metal . .	0.144	...	trace	0.051	0.064	0.072
	Spiegel . . . .	15.60	0.80	3.34	1.77	...	...
	Steel . . . . .	0.83	none	0.30	0.117	...	...

The above heats were blown from a mixture of the following pig irons in the proportions named in Table III.

TABLE III.—*Charge of Heats in Table II.*

Brand or Material.	Cwts.	Average Analysis.					
		Mn.	Graphite.	C. Carbon.	Si.	S.	P.
Millom hæmatite .	20	...	3.20	0.76	2.35	0.10	0.02
Askham „ . .	10	0.93	4.50	0.20	3.15	0.08	0.04
Carufoth „ . .	35	...	3.62	0.18	2.55	0.06	0.12
Ditton Brook „ .	30	...	3.16	0.37	3.04	trace	0.04
Swedish plate „ .	10	1.987	4.809	...	0.176	trace	0.122
Metal scrap . . .	10	...	...	...	...	...	...
Steel scrap . . .	20	...	...	...	...	...	...
Spiegel. . . . .	8	...	...	...	...	...	...

It will be seen in Table II. that in every case the spiegel contained a certain proportion of graphite, whilst invariably the finished steel only contained carbon in the combined form.

The importance of this fact will shortly be noticed.

\* The author regrets he has no analysis of the Swedish pig or plate used, so that given by Percy in his "Iron and Steel," p. 736, is included in the table for comparison.

## THE SPIEGELEISEN AND FERRO-MANGANESE.

Spiegeleisen originally came from the Continent, and generally contained a low percentage of manganese—from about 5 to 10 per cent. The manufacture of this material had not long been started in England when the author began his Bessemer practice, and it gradually became the tendency to go on increasing its manganese contents, the demand settling down to anything from 20 to 25 per cent. The consequence was that experience was gained with spiegel of very varying percentages.

Occasionally there would be the disposition to use a spiegel with little manganese as pig iron, but this was checked by the knowledge that to put unnecessary manganese into the cupola was unwise owing to its action on the lining.\*

Every inducement existed therefore to work up the spiegel in its proper place at the end of the process, and that this could be done without detriment, notwithstanding its occasionally containing graphite, the analyses in Table II. plainly show.

Table IV. gives analyses of Continental spiegels such as had been in use before the material was made in England. The fact that such spiegel had been used with perfect success notwithstanding its contents of graphite soon caused one to have the fullest confidence in the English product. Even when this contained as much graphite as the Continental, the proportion in relation to the manganese was generally smaller. †

TABLE IV.—*Continental Spiegeleisen.*

Mark.	Mn.	Graphite.	C. Carbon.	Si.	S.	P.
M . . . . .	4·60	0·45	4·10	1·23	0·16	0·12
S . . . . .	5·86	0·40	4·10	0·96	0·26	0·03
S <sub>1</sub> . . . . .	6·44	0·70	3·00	0·14	0·07	0·04

\* A cupola slag analysed in 1873 gave—

	Per Cent.
Silica . . . . .	40
Hence silicon . . . . .	18·67
Oxide of manganese . . . . .	38·50
Hence manganese . . . . .	29·83

† The excellence of the material made with low-grade spiegel may be inferred from the fact that in 1885 the author learnt when at Chicago that the Chicago and Alton R.R. treasured for making frogs some old rails supplied by John Brown & Co. many years before. He found similar appreciation of John Brown & Co.'s rails at the St. Paul, Minneapolis, and Manitoba R.R.

## THE CARBON.

Thirty years have not altered the chief characteristic of steel, for that indefatigable investigator, R. A. Hadfield, has recently written:

"But, singular as it may seem, notwithstanding the important part played by all these new iron alloys, carbon still maintains its premier position in determining the practical value of the various products; in other words, there are few, if any, iron alloys in which, apart from the effect produced by the special element added, the presence of carbon is also unnecessary, therefore whatever the theory believed in by each reader of this article, that is, whether he is a carbonist or allotropist, it has to be admitted that carbon alone is the predominant factor in determining the utility of the alloy."\*

Holding this very view in regard to the carbon, it was little wonder that the author took up his work imbued with the great importance of this element, and that to obtain the exact percentage needed in a steel as shown by analysis became his chief aim. The modern Bessemer manager would appear to have still greater reason for thus acting after Mr. Guillet's determination of the numerical value of the equivalent of the principal modifiers of iron which lower by the same amount the points of transformation upon the scale of temperatures. The figures quoted by Hadfield are 1.65 parts of hardening carbon as equivalent to 12 parts of manganese and to 29 of nickel.† This is very nearly the generally accepted ratio of 1 carbon to 7 manganese, so that, for example, a deficiency of manganese in the steel of 0.5 per cent. would be more than made up by 0.1 per cent. of carbon.

The following was the plan adopted to introduce the requisite amount of carbon into the blown metal to make it into the right kind of steel.

An easy calculation will show that—

If  $x$  = cwts. of spiegeleisen required,  
 $C$  = per cent. of carbon in spiegeleisen,  
 $B$  = cwts. of blown metal,  
 and  $n$  = per cent. of carbon desired in the steel,

then 
$$x = \frac{nB}{C - n}.$$

Hence for the 10-ton converters yielding a charge of blown

\* *The Iron and Steel Metallurgist and Metallographist*, vol. vii. 1904, p. 20.

† *Ibid.*, p. 18.

metal weighing 190 cwts., the formula when desiring to produce steel with 0·30 of carbon was—

$$x = \frac{57}{0-0.3}$$

and a handy table was calculated, from which one could see at a glance the weight required for each percentage of carbon contained in the spiegel.

TABLE V.—*Showing cwts. of Spiegel required to produce Steel with 0·30 Carbon in a Charge of Blown Metal of 190 cwts.*

Total Carbon in Spiegel.	Cwts. Required.	Total Carbon in Spiegel.	Cwts. Required.
5 per cent.	12·12	4 per cent.	15·4
4·75 „	12·8	3·75 „	16·6
4·5 „	13·5	3·5 „	17·8
4·25 „	14·4	3·25 „	18·6

This table being for 10-ton converters is of easy modification for those of any other size.

It can be imagined that it was not an easy matter to always dispose satisfactorily, even with the aid of the above table, of such varied materials as those that have been described. Nevertheless, by means of great attention to the bending and the carbon tests, one of which was taken for every blow made, success was achieved. When, however, these got mixed through wrong marking and failed to represent the true heats, steel might go forward not quite suitable for the purpose intended. The necessity for such constant and accurate watch is easily understood when it is considered that a charge from the cupola might be tapped before being completely melted, that the weight of the spiegel might also be deficient, &c. No men were, however, more amenable to instruction than those in charge of the various sub-departments, and the author soon was able to only have to look to his own deficiencies for any failure.

#### THE MANGANESE.

Now on coming to grips with the synthesis of Bessemer steel the author certainly felt the need of some “key”

to the situation that the management of the carbon did not give.

Of course, every one connected with the Bessemer manufacture was aware of the controversy between Bessemer and Mushet, and the important part played by the manganese of the spiegel in the deoxidation of the blown metal. Sir H. Bessemer has himself told how he bought back his first licences for £31,500, which one can see was clearly because of the inability of those who took them up to work the process in its original form.\*

Without the modification due to R. F. Mushet's ingenuity, namely, the use of spiegeleisen to recarburise, the process was a failure, but the action of the manganese contained in the spiegel was regarded simply as that of a scourer. The aim of the Bessemer steelmakers seemed to be to employ as little as might be of the manganese for the removal of oxygen whilst leaving in the steel all the necessary carbon.

That the manganese did something more than merely clear the steel of oxygen impressed itself strongly on the author's mind, when on one occasion very good steel was being turned out from one set of converters whilst that from another set was only passable.

The mixtures of pig used are given in Table VI., together with the manganese and combined carbon found in the steel.

TABLE VI.—*Composition of Charges used in the Manufacture of good and of passable Steel.*

Hæmatite Pig-iron Brand.	Very good Steel.		Passable Steel.	
	Cwts. .	Per cent. used.	Cwts.	Per cent. used.
Local . . . . .	10	7.7	30	15.8
Barrow, No. 3 . . . .	30	23.1	30	15.8
West Cumberland . .	50	38.5	60	31.6
Moss Bay . . . . .	...	...	20	10.6
Cleator . . . . .	10	7.7	20	10.6
Swedish . . . . .	20	15.4	20	10.6
Mould scrap . . . .	10	7.7	10	5.3
		100.1		100.3
Mn. in the steel . . . .		1.17 per cent.		0.98 per cent.
C. carbon in the steel . .		0.33 „		0.29 „

\* *Journal of the Iron and Steel Institute*, 1898, No I. p. 303.

The most natural deduction to make from the above figures was that the local pig was at the bottom of the mystery, and a thoroughly representative sample was analysed, with the following results:—

Combined carbon . . . . .	0·20	} 3·88 per cent.
Graphite . . . . .	3·68	
Silicon . . . . .	3·69	„
Sulphur . . . . .	0·158	„
Phosphorus . . . . .	trace	

The presence of 0·158 of sulphur was quite insufficient to explain the marked difference between the two steels. Hæmatites were frequently found to contain as much, and even larger quantities; for instance:—

Askham No. 3 had contained . . . . .	0·123 of S.
West Cumberland No. 3 had contained . . . . .	0·235 „
And even Millom No. 1 had contained . . . . .	0·135 „

These had constantly been used in mixtures without detriment, so that one could not look upon this as the solution.

The matter was looked at from various other standpoints, such as the greater purity of the Swedish pig iron, the absence of Moss Bay from one of the mixtures, &c., but they were none sufficient to carry conviction as to any of them being the true cause of the mystery. What one, however, may term the “residual” difference remained—namely, the larger amount of manganese present in the very good steel. It was forced upon one that the much better quality of the one steel was due to the slightly greater quantity of manganese that it contained over the other.

The author's experience had been leading up to this, for he had already found that by proper manipulation of the manganese sound ingots free from honeycombs could be obtained. As direct rolling was being introduced, this was a most important matter. By using the exact quantity of spiegel to introduce 1·35 per cent. of manganese into the charge, the object was most successfully accomplished.

To satisfy not only the rail-mill manager but also the tire-mill manager, and the forge manager who had to use it for axles, every one of them pronouncing it “the best steel ever made,” was enough to make one think that the “key” had at last been found.

And yet some eminent metallurgists have been unable to believe this. The most venerated in this connection, viz. R. F.

Musket, in a letter to the author, in April 1884, wrote: "But, and here I expect we shall have to agree to differ, manganese in alloy with steel never did, never can, improve it as steel, and this I shall endeavour to prove when I try in *Iron* to clear away some cobwebs, *re* Heath's process and mine."

Not so does H. M. Howe express himself in that monumental work, "The Metallurgy of Steel." He says that in 1872 four distinguished steel metallurgists gave him the figures 0·5, 0·5, 0·75, and 1 per cent. respectively as the highest amount of manganese which should be tolerated in Bessemer rail steel under any conditions whatsoever, but finds that "to-day" (1891) rail steel occasionally contains as much as 2·1 per cent. of manganese, and frequently as much as 1·55 per cent.\*

Now, it is perfectly certain that whilst the proper employment of the manganese, as the author found, is the key to the Bessemer process, still the percentage to be used will depend largely on the composition of the mixtures employed, *i.e.* on the chemical composition of the charge. No. 2, Table I., gives a fair idea of what the mixtures were that he employed. They would not greatly vary from this in a twelvemonth, for although the brands of iron used kept changing, so many were put into the mixture that it would be necessary to have had some very bad brand to materially affect the composition.†

### RAIL STEEL.

And the question here suggests itself, Are the irregularities of modern Bessemer rails due to direct working from the blast-furnace? It certainly would seem impossible to obtain so regular a product as in the old way, although a 325-ton mixer should do something towards overcoming the difficulty.‡

But to return to the manganese.

With the mixtures usually employed, analyses of which have

\* "The Metallurgy of Steel," second edition, p. 46.

† The value of this precaution was illustrated on one occasion when some iron rejected by another steel-maker was sent to us, and was used up without detriment. As the makers of the iron entered an action against the steel-makers, we were soon made acquainted with the meaning of *Subperna cum duois tecum*, but they lost the case nevertheless. Had that brand alone been used for a charge by us, perhaps a similar rejection would have ensued.

‡ *Journal of the Iron and Steel Institute*, 1902, No. II. p. 475.



been given, it was found that for rail steel so much spiegel should be used as for the manganese to equal 1.35 per cent. of the resulting steel, *whatever might be the manganese that remained in the steel*. It will be well for clearness to call this figure the *synthetical manganese*, as the whole of this amount would, of course, not be left in the finished steel, which on analysis might not show more than 1 per cent.

A table was prepared for the manganese in the same manner as explained for the carbon (see Table V.), and by working with it steel giving much more uniform mechanical tests than had been the case before resulted. This was so notwithstanding that the carbon tests might show considerable differences, certainly a result that was as surprising as it was welcome, for working within limits, and not straining the law too far, it was the easiest thing in the world to regulate the manufacture, in spite of the great number of strengths of spiegeleisen that had to be used.

Hadfield has said: "In metallurgical research conflicting reports, unfortunately, often occur on experiments apparently of the same nature; hence the importance of giving, in such work, as full details as possible."\* It is regrettable, therefore, that on this point memory alone has to be trusted, and that a series of tests cannot be given. The uniform character of the deflection and of the shape of the broken piece that came away from the test-pieces of rail at the drop are, however, well-remembered facts.

The tests were probably not as severe as those imposed at the present day, but neither would the sections be as heavy.

#### STEEL FOR AXLES.

Except that a considerable proportion of Swedish pig was used in the mixture, the synthetical manganese necessary for axles was practically as when making rail steel, viz., 1.35 per cent.

The Landore Company, however, was introducing its "Siemens" steel for this purpose, and some of the railway companies made their tests more severe. For instance, the requirements of the Midland Railway Company became that the test axles "must be capable of

\* *Proceedings of the Institution of Civil Engineers*, vol. xliii. Part III. p. 6.

standing, without fracture, five blows from a weight of 2000 lbs. falling from a height of 20 feet upon the axle, which shall be placed upon bearings 3 feet 6 inches apart, and turned after each blow." \*

The axles weighed 430 lbs.

For this purpose the synthetical manganese had to be reduced, and just over 1 per cent. was found to produce the required steel which contained carbon in the neighbourhood of 0.25.

### STEEL FOR TIRES.

Swedish pig iron generally formed part of the mixture for making tire steel. The synthetical manganese was 1.25 per cent., as a rule.

### SPRING STEEL.

This was the kind of steel where the presence of carbon above a certain limit became an obvious necessity. No amount of manganese made up for the want of carbon where the finished product had to be hardened and tempered. Still there was no difficulty by the choice of suitable spiegeleisen containing from 15 to 17 per cent. of manganese and about 5 per cent. of carbon to introduce sufficient carbon into the steel to give perfect satisfaction for the manufacture of laminated springs. To get 0.45 per cent. of combined carbon in the steel was generally one's aim.

### CONICAL SPRINGS.

It was, however, the manufacture of steel for coiled springs of numerous designs that tried the mettle of the Bessemer manager, as no other occupation could possibly have done.

Every one is now familiar with the conical spring that John Brown patented, of which some early forms that have survived to the present day are represented in the accompanying plate.

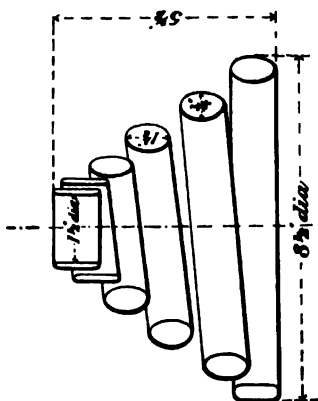
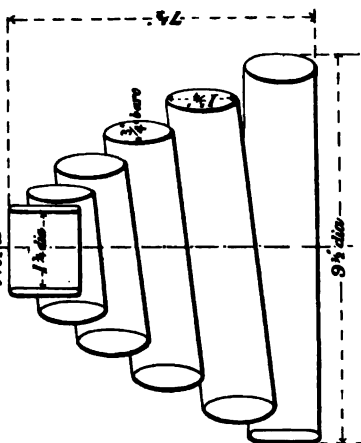
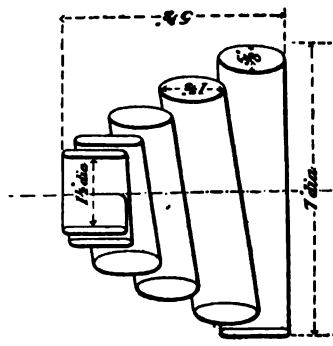
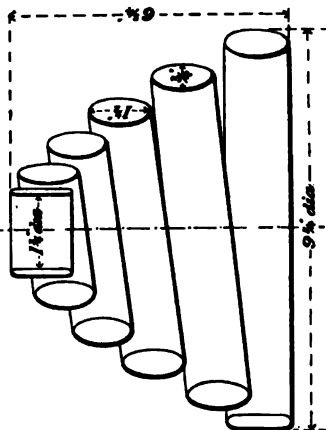
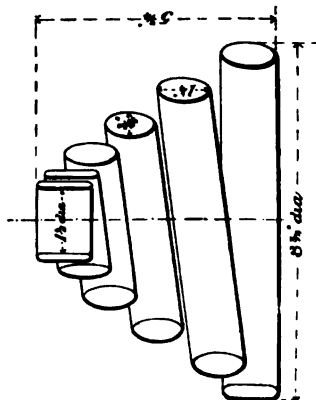
\* It may be worthy of note that some discussion arose on one occasion as to the equivalence of 1 ton falling through 17 feet 10½ inches with 2000 lbs. falling over 20 feet. A rail was cut into three pieces, and tested on bearings 3 feet apart, with results as follows:—

(1) 10 cwt. falling 30 feet, first blow, deflection, 4½ inches.

(2) 20 cwt. " 15 " " " " 4½ "

(3) 20 cwt. " 7 feet 6 inches, first blow, deflection, 2½ inches } 4½ inches.  
20 cwt. " " second blow, " 2 " }

which practically proved the equivalence of the two tests referred to for 2240 lbs.  $\times$  17 feet 10½ inches = 2000  $\times$  20 feet. These tests also proved the homogeneity of the rail.

*Regular 9 inch**Normal**Improved**Regular 11 inch**Regular 10 inch*

CONICAL SPRINGS

AS MADE IN 1874

BY

JOHN BROWN &amp; CO. LTD

Every spring, after manufacture, and before it left the works, was tested by dropping a heavy weight upon it from a considerable height, so that the spring was momentarily flattened by the blow into a plain spiral. The spring, if good, resumed its original shape and sent the weight flying up into the air, which falling again upon the spring the action was repeated. This went on a few times with diminishing force and increasing rapidity until the heavy weight came to a standstill. If the steel from which the spring was made was all right, it underwent the ordeal without any damage. If the steel was too soft, the springs became more or less flattened and had to be rejected just as when they broke through the steel being hard. In the technical language of the craft, the springs that became more or less flattened were called "low." \*

With the success attained in the manufacture of Bessemer steel for the varied requirements of rails, tires, axles, plates, and forgings, it would seem an easy matter to obtain analyses of good and bad springs and go ahead successfully by imitating the good ones. This, however, is easier said than done.

There is no doubt that analysis is indispensable in most modern manufactures; but there are, nevertheless, many points in the synthesis of production that it is very difficult, if not impossible, to discover by analysis. †

At the same time, analysis is the only possible starting point in any difficulty, and all the assistance that this method of procedure could give was sought. The following table will show this.

TABLE VII.—*Analyses of Spring Steels.*

Steel.	Mn.	Graphite.	C. Carbon.	Si.	S.	P.
Good conical . . . . .	0·896	0·05 (?)	0·39	0·201	0·083	0·134
„ second estimation	0·872	...	0·38	...	...	0·139
Brittle conical . . . . .	1·168	0·05	0·54	0·089	0·334	0·165
„ second estimation	...	...	0·54	...	...	...

\* Steel-makers who feel compelled to subject their products to so much testing may find consolation in the fact that even the best astronomical telescopes have been produced by frequent trials, and that Herschell often made a hundred without hitting upon a good one. See "The Home Life of Sir David Brewster," second edition, p. 43.

† In the dispensing of some medicines, for instance, certain ingredients have to be put into the mixture before others in order to make a successful potion. The secret of some good inks is the slight roasting of the galls used. It would be impossible by analysis to discover such details.

The fact that the good conical contained nearly two and a half times the amount of silicon that the bad or brittle one did is certainly remarkable. As, however, for conical springs the ingots have to be of the soundest character, it is a circumstance that should cause no surprise, knowing the ratio established by Brinell between silicon and manganese, viz. 1 to 5·2, or that "there is 5·2 times more manganese required than silicon in order to obtain ingots of equal density." \*

There seems to have been some doubt as to the presence of any graphite in the good steel, but after what has been said on the point, the presence of this form of carbon, even in the brittle steel, seems anomalous. In any case, from the larger amount of manganese and combined carbon present in the brittle steel, too much spiegeleisen would seem to have been used in its manufacture. The nearly quadruple quantity of sulphur in the brittle steel must have also greatly influenced its character.

It was natural that in the manufacture of such special steel the attempt should be made to get the most perfect mixing. This was done by turning up the converter after the addition of spiegel and blowing through for a moment. Sometimes this after-blowing would be continued for four seconds.

But it was found to be a fallacy to suppose that any stirring of the molten steel is necessary to give it homogeneity. The cause of this is easily explained, viz. that when a heat has to be turned up more synthetical manganese must be used, and of course the after-blow may do one of three things: (1) It may just take out the extra quantity added; (2) it may not do so, leaving an excess; or (3) it may take out too much. If an excess be left, the steel is hard and brittle; if too much is taken out, the steel is soft, and the springs made from it are "low."

The important point to note, however, is that this very special steel could be made of an absolutely perfect quality without stirring, proving the needless character of this complication of the process in every other instance. It was also found that mixtures of English hæmatites without any admixture of Swedish were of perfect quality for the special purpose of making conicals. The manganese used had to be well in the neighbourhood of 1·25 per cent., whilst the combined carbon found

\* *Journal of the Iron and Steel Institute*, 1902, No. I. p. 347.

in the steel had to reach 0·40 or so, and not rise much above 0·45.

### CONCLUSION.

No one will be surprised to learn that the Bessemer converter has been discarded for conical spring steel, which is now made in the Siemens furnace. But the circumstance that already in 1874 it was possible to manufacture so delicate a material by the pneumatic process with the success that was at last achieved, plainly shows that the manufacture of rails with perfect regularity was mere child's-play. It is inconceivable that the Bessemer converter should not to-day, or even with the added complications of the basic form, be also able to supply uniform material, whatever modern requirements may be, if only the proper procedure is understood.

It is indeed to be hoped that a process that has done such great service in the progress of railway communication throughout the world, and hence in the cause of civilisation, which, like the railway system itself, owes its existence to Englishmen, will be capable of restoration in the country of its birth to that confidence that it once possessed, and that it well deserves. Worthy successors to George and Robert Stephenson, and helpers in carrying on their legacy of work, are such names as Bessemer and Mushet, followed by Snelus, Thomas, Gilchrist, and Cooper, who made the basic process possible—all English names; and even Holley, to whose ingenuity the marvellous records of which we read are due, was a citizen of that great English-speaking country that once formed part of this empire, and which our president has done so much to win back, if not to political union, yet in that bond of amity that makes for peace and progress, in the results of which every other nation shares.

This paper has been written in the hope that a discussion may help to bring about any improvement that new conditions may have rendered necessary.

*CORRESPONDENCE.*

Professor J. O. ARNOLD (Sheffield) wrote that he was in substantial agreement with Mr. Carulla's paper. He had himself found it desirable to work the manganese in Bessemer steel up to  $1\frac{1}{2}$  per cent.

Sir LOWTHIAN BELL, Bart., F.R.S., Past President, wrote that as a Director of the North-Eastern Railway he had arrived at the conclusion that it would be unsafe to lay down any hard and fast line in order to connect failure with the composition of a rail. The author in his instructive paper refers incidentally to the possible increase of the open-hearth process. In his (Sir L. Bell's) opinion this mode of manufacture is applicable in an economical point of view to the production of steel rails. That the open-hearth principle is growing in favour is proved by the gradual and recently rapid increase, as compared with the Bessemer process, in the United Kingdom.

Year.	Bessemer Steel.	Open-Hearth Steel.
	Tons Made.	Tons Made.
1868 . . . .	110,000	520
1878 . . . .	820,447	175,500
1903 . . . .	1,910,018	3,124,083

These figures, which speak for themselves, are given partly on account of his having been taken to task for what was regarded as a groundless statement in reference to the growing importance of the open-hearth process.

Mr. A. H. COOPER (Port Clarence) said: On page 292 Mr. Carulla states that "Sir Lowthian Bell has expressed an adverse opinion of Bessemer rails," and says that "it is inconceivable that he can bring the acid process under this ban." The North-Eastern Railway Co. (of which Sir Lowthian Bell is Vice-Chairman) has had a far larger experience of basic rails than any other railway in the country, and their experience has fully proved that basic Bessemer rails are far more reliable than acid Bessemer rails.

Over a period of six years, viz., from 1894 to 1899 inclusive, out of 230,000 tons of basic Bessemer rails 62 breakages occurred, or one breakage for 3706 tons; out of 121,952 tons of acid Bessemer rails 161 breakages occurred, or one breakage for 757 tons.

At the Clarence Steel Works large quantities of basic Siemens steel rails have recently been made for India and for South Africa, and we have been much struck by the very rigorous tests they uniformly stand; far more severe than can be obtained from Bessemer steel rails.

One of the reasons is that it is possible to work with a much lower manganese than in the Bessemer processes. Rails high in manganese in the presence of high carbon are unquestionably unreliable when subjected to shocks. Again, by the basic Siemens process the sulphur and phosphorus can also be got down much lower than is possible in either of the Bessemer processes.

Mr. PERCY C. GILCHRIST, F.R.S., Vice-President, said his impression was that a limit of 0·6 to 0·8 per cent. of manganese is much better than the higher limit that the author found necessary some years ago. Of course 0·6 and 0·8 are only possible when the sulphur does not rise above 0·06, and when the bath has not been over-oxygenated. He thinks that it has long been admitted that the proper hardening element in steel is carbon, and that only so much manganese should be permitted as is necessary to correct the red-shortness that may be due to either sulphur or oxygen, and that it should not be used for hardening purposes. The most reliable steel or ingot iron is that which has been produced from a metal that is least red-short before the addition of either ferro or spiegel.

Mr. R. A. HADFIELD, Vice-President, said he had read Mr. Carulla's paper, "The Synthesis of Bessemer Steel," with much interest, as he gave historical data which should be of considerable value.

As regarded the relative hardness produced by carbon and manganese, mentioned in paragraph 3 on page 295, it would of course be understood that this factor—if one might term it so—



was suggested by Mr. Osmound, and he did not think he intended it to apply for steel in which the manganese was present in comparatively small percentages. For example, personally, he would not like to state that 0·5 per cent. of manganese was equal to 0·1 per cent. of carbon, it was only in the higher percentage alloys where the ratio he quoted would apply. Why that should be so was difficult to explain.

As regarded the quality of Bessemer steel, it must not be forgotten that in the past this process had been used where enormous output was required, the quality of the material produced taking secondary place. That high quality material could be produced under it was proved by the excellent Bessemer steel made in Sweden, where quality of output occupied the secondary, and quality of product the first position.

With Mr. Carulla's final conclusions, that high quality could be produced with proper treatment, he quite agreed.

Mr. COSMO JOHNS, Sheffield, wrote that he was much interested in Mr. Carulla's account of the early struggles of the Bessemer steel manufacturer. Apart from the usual difficulties attending the use of the Bessemer process, he could not help thinking that the high sulphur and phosphorus found in the pig iron used in those days was responsible for many of the troubles. Table VII., with its good and its brittle spring, explains itself; 0·083 sulphur and 0·139 phosphorus would be much too high, but the second one with 0·334 sulphur and 0·165 phosphorus would not only be brittle, but the sulphur is so high, that the only wonder is that it could be worked at a red heat. To-day, good steels can be made by the pneumatic process, but only when output is made a secondary consideration, and even then the greater facilities for control afforded by the acid open-hearth process will always relegate the Bessemer converter to a secondary position. The much greater yield in the open-hearth process is another great factor. Silicon bought at pig iron prices is a very expensive form of fuel.

Mr. F. J. R. CARULLA in his reply thanks Mr. Hadfield for his remarks on the relative hardness produced by carbon and manganese in the various alloys, which, coming from him, have so much authority. Mr. A. H. Cooper quite confirms his own

opinion that the basic process can produce material as reliable as any obtainable by the acid process. The comparison of the breakages of the two kinds of Bessemer rails—acid and basic—fully proves the superiority of the latter, and Mr. Cooper's opinion as to the evil of high manganese in the presence of high carbon is fully confirmed by all experience. The rails referred to in a footnote of the paper, made in the early days of the Bessemer process, and that were so treasured in the United States, would be high in carbon and comparatively low in manganese, as the spiegel of that time was of very low percentage. With such spiegel, what in the paper has been called the "synthetical manganese," would have to be modified; but none the less, in order to attain success, the manager would have to look to the manganese rather than the carbon during manufacture. It is here that Mr. Hadfield's remarks throw much light, for were 0.5 per cent. of manganese equivalent to 0.1 per cent. of carbon, it would be less dangerous to be careless of the manganese than of the carbon, whereas the opposite is the case. It must also be remembered in this connection, that in the early days of the Bessemer process the hæmatite pig iron used (Cleator) was exceptionally pure, and was unobtainable in sufficient quantity for later practice. With such iron, low in sulphur and phosphorus, it was possible to work as Mr. Gilchrist suggests. It is because of the possibility of so largely eliminating these undesirable elements in the basic Siemens furnace, that, as Mr. Cooper points out, this process is so reliable.

In the presence of any considerable amount of these impurities, especially sulphur, as Mr. Gilchrist and Mr. Parry indicate, the manganese must be increased, and 0.896 was sufficient to correct the effect of what Mr. Johns seems to consider should have caused the good conical steel of Table VII. to be red-short. This, nevertheless, was a perfect steel for its purpose, and justifies Sir William Siemens' belief that manganese may be a cloak for impurities, without his necessarily being illogical.\* It is quite possible for manganese to play more than one rôle in the constitution of steel, and it is evident from

\* "Not a few now regard manganese in moderation as harmless, or even beneficial . . . but, making all allowances for prejudice, many intelligent and unbiassed metallurgists dread it, and echo Siemens' illogical complaint that it is a cloak for impurities."  
—Howe's "Metallurgy of Steel," vol. i., 2nd ed., p. 46.

Mr. Hadfield's remarks that we have not yet exhausted the study of its various effects.

The figures given by Sir Lowthian Bell are striking as to the advance of the open-hearth process. The opinion of Mr. Johns is well supported by them. Nevertheless, that there should be made yearly in the United States some nine million tons of Bessemer steel, of which two and three-quarter millions are rails, goes some way to show that conditions still exist favourable to the Bessemer process in spite of its costly fuel. The author hopes therefore that the principle advanced in the paper, supported as it is by the eminent authority of Professor Arnold, whose experience coincides with that of the author, may have been of service to improve an important manufacture of which in some cases there appear to have been just grounds of complaint. Mr. Parry's suggestion of a hot mixer for Bessemer steel seems a very practical one, and well worth a trial.

THE THERMAL EFFICIENCY OF THE  
BLAST-FURNACE.

BY W. J. FOSTER (DARLASTON)

MUCH has recently been published by different authorities on blast-furnace practice, describing the great difference between the English practice as compared with that of America from an economical point of view, and the difference is considered to be due to the enormous outputs of the American furnaces as compared with the small outputs of the furnaces in this country. Although the subject has been in this way thoroughly explained, yet it seems to me that there is a great field open for research from a combined practical and theoretical point of view, and I think the time has now arrived when this question, especially in Great Britain, should have serious consideration.

Although the subject of the thermal efficiency of the blast-furnace was a question that drew the attention of the Iron and Steel Institute to one of the first papers which was read before this Institute by Sir Lowthian Bell, it appears to me that the question has not had the amount of attention from any other author that it really deserves, especially during the last few years.

The particular furnace that I have under examination, although not equipped with modern machinery and blast-heating apparatus, &c., may be interesting from the fact that the materials used were chiefly silicates of iron, in the form of flue and tap cinders, together with a small quantity of ferric oxide; it is the furnace at present blowing at Darlaston, having a height of 72 feet 6 inches, and a capacity of 16,000 cubic feet.

Since Neilson's time many attempts have been made to describe technically the theory of hot-blast as applied to the blast-furnace. Among the most important authorities are Professor W. A. Miller of King's College, London, Professor Clark of Aberdeen University, Dr. Percy, and Sir Lowthian Bell. The three former investigators base the theory upon the deficiency

of heat in the hearth, which left us very little more in advance than Neilson's explanation, while Sir Lowthian Bell considers the heat actually taken into the furnace by the blast, which is measured in the form of calories by simply multiplying the weight of the blast by its specific heat and its temperature, which he considered would account for the reduction of fuel. He also remarks that, by increasing the capacity of a cold-blast furnace, we should have something like the same effect as regards the fuel consumption as that realised by the introduction of hot-blast at the tuyeres, but from my own experience I do not find this to be the case in Staffordshire when smelting mill cinders, &c., which is the custom in this particular district. Nevertheless, this train of reasoning would be absolutely correct in an ideal blast-furnace, where the quantity, composition, and temperature of the escaping gases per unit of iron made would be the same with the application of either hot or cold blast respectively. It must be understood also that, to make the above law correct in an ideal furnace, which of course we do not possess at present, we must take into consideration the increased heat absorbed by the hot-blast at high temperatures, which is due to the partial dissociation of the water molecule before entering the furnace, which has a constant value, being proportional to the temperature and pressure; and is governed by the fact that, at a white heat, water vapour is completely decomposed without the intermediate action of any other body; consequently, the whole of the heat due to decomposition is not to be accounted for in the hearth of the furnace. For example, at Darlaston I found that 6.376 units of air are required per unit of pig, when using cinder as mentioned above, and the fuel consumption at the time of examination was 1.46 tons, which may be represented by the simple formula,  $6.376 \times 454.4^{\circ} \text{C.} \times .24 = 695.34$  calories; the quantity of water vapour entering the furnace per unit of pig was found to be  $.00624 \times 9 = .05616$ , so that the heat formation should be  $.00624 \times 34462 = 215$  calories.

It will be seen that the 215 calories, minus the latent heat of the water existing in the blast, may be represented thus—

$$(.00624 \times 34462) - (.00624 \times 9 \times 537) = 184.842;$$

so that 184.842 calories would be absorbed at the expense of

the fuel in the hearth; but in the case under examination, where the air is allowed to pass into the furnace at  $454.4^{\circ}\text{C.}$ , the heat absorbed in the hearth would still be less than shown above, and may be represented by the following formula to be  $(.00624 \times 34462) - [(.00624 \times 9 \times 537) + (.00624 \times 9 \times 454.6 \times .4805)] = 172.58$  calories, so that the actual heat taken into the furnace with the hot-blast would be

$$(695.34) + (215 - 172.58) = 737.76 \text{ units.}$$

Now, applying this method to the furnace at Darlaston under the conditions given, I find that the calories injected into the furnace with the blast equal  $2.075$  cwts. of coke per ton of pig. As a matter of fact, I find that, under the conditions mentioned, a lowering of the temperature of  $200^{\circ}\text{C.}$  alone would more than account for this quantity; consequently we must look for another theory to explain the hot-blast problem, for under these conditions it is quite evident that the theoretical limit for the advantage of heating the air with such materials as flue cinders, &c., would only occur when the quantity of carbon in the hearth is not sufficient to combine with the oxygen of the ore and metalloids which would be reduced in the hearth and lower part of the bosh. It is quite certain that to decompose and reduce the silicates and phosphates of iron, &c., in the neighbourhood of the hearth and tuyeres with a minimum supply of air-blast per unit of iron, would certainly lead to great economy of fuel; but to reduce these bodies, which are endothermic at  $0^{\circ}\text{C.}$ , would require a very high temperature to convert them into exothermic bodies, which must necessarily be the case in the hearth, if we are to utilise the oxygen from these bodies with advantage to oxydise the carbon when approaching the hearth of the furnace with proportionally less atmospheric air per unit of carbon burnt.

It is quite evident that to ascertain the true nature of the hot-blast theory by means of a mathematical problem would require a thorough knowledge of the physical and thermo-chemical conditions of all the matter involved in the process. This opens out a large field for research, which will not only solve the hot-blast problem, but also the true nature of the whole system.

The following table gives the necessary information of the

heat evolved by 1·46 tons of coke, and appropriation of heat to the different branches of the process, calculated from an average approximate knowledge of the weight and analysis of all the matter involved throughout the system. The mode of calculation, which I insert in the appendix, was found to be very nearly the truth, as far as the analysis of the gases from the furnace was concerned. Column I. represents the calories for combustion in the coke. Column II. represents cwts. of coke for the different parts of the system, and Column III. shows the actual cost of the different parts in shillings when the total cost of fuel per ton of pig equalled 23·36 shillings:—

	I.	II.	III.
Reduction of iron oxide . . . . .	1391·000	3·912	3·130
Reduction of silica . . . . .	254·470	0·716	0·578
Reduction of phosphorus . . . . .	85·630	0·241	0·193
Reduction of oxides of sulphur . . . . .	0·660	0·002	0·002
Reduction of oxides of manganese . . . . .	18·090	0·051	0·041
Reduction of calcium in slag existing as sulphide . . . . .	38·437	0·108	0·078
Expulsion of CO <sub>2</sub> from flux stone . . . . .	236·910	0·665	0·534
Heat carried off by gases, including water in coke . . . . .	769·446	2·164	1·732
Fusion of pig iron . . . . .	330·000	0·928	0·743
Decomposition of water vapour in blast . . . . .	172·580	0·478	0·390
Fusion of slag . . . . .	548·310	1·542	1·235
Heat carried off by tuyere water . . . . .	50·992	0·144	0·117
Heat carried off by cooler water . . . . .	31·871	0·089	0·072
Carbon taken up by pig iron . . . . .	282·800	0·796	0·637
Loss due to radiation and absorbed in foundations . . . . .	727·164	2·052	1·635
Combustible matter in gases . . . . .	5444·440	15·312	12·248
Total heat, coke, and cost from 1·285 carbon in the coke . . . . .	10582·800	29·200	23·360

The first item in Column I. represents the amount of calories required to remove the oxygen from ·9068 unit of iron introduced into the furnace for the reduction of one unit of pig iron, and in a similar manner for the quantity of silicon, phosphorus, sulphur, and manganese, taken up per unit of pig. It will readily be seen that the heat value for iron oxide is lower than has hitherto been assumed; the usual value being taken from 1780 in furnaces using ferric oxides, but in this particular case the value is reduced, owing to having less oxygen in the material, and to making due allowance for the returned scrap which is added to the charge. The average quantity of oxygen added to the

charge was estimated by analysis in the usual way. There is a very important point which I think is worthy of consideration from a thermo-chemical point of view in connection with the heat formation of the various oxides of iron, &c.; for example, it is usual to ascertain the thermal value from magnetic oxide ( $\text{Fe}_3\text{O}_4$ ), which, by Andrews' calculations, is represented by 265·8 kilogramme units for 168 parts of iron and 64 parts of oxygen. The ferrous and ferric oxide values are quantities given in proportion to the oxygen actually taking part in the reaction, but to my mind the value of the different oxides of iron should be in proportion to the total atoms actually involved in the chemical change, assuming that the physical conditions of the matter undergoing the various chemical changes are the same; for example, 232 units of matter, or seven atoms in magnetic oxide ( $\text{Fe}_3\text{O}_4$ ), produce 265·8 large units of heat, consequently ferrous oxide ( $\text{FeO}$ ) contains 72 parts by weight of iron and oxygen with two atoms, therefore the heat value should be  $7 : 265\cdot8 :: 2 : 75\cdot94$ , instead of 66·4, as shown by the law represented above, which is estimated from the quantity of oxygen alone, and similarly ferric oxide ( $\text{Fe}_2\text{O}_3$ ) containing five atoms should be represented by  $7 : 265\cdot8 :: 5 : 189\cdot86$  units instead of 199·4. Of course, as previously mentioned, these figures are not absolutely true owing to the fact that the solid iron would be oxidised by gaseous oxygen; consequently, to arrive at the true values, we should have to get an exact knowledge of the difference in the specific heat of solid oxygen and gaseous oxygen.

It will be seen that the heat absorbed by the quantity of slag necessary to produce one unit of pig is represented by the value 548·31 calories, the quantity of slag per unit being 1·119 units, so that the actual value attributed to one unit of slag is 490 calories, which is an average of twenty experiments taken from the molten slag at the nearest point to the slag notch in an apparatus which I constructed specially for the purpose; the highest value, 514·5, was obtained when the furnace was working very hot, and the cinder being very grey and limey; on the other hand, the lowest value, 451, was obtained when making forge pig with a dark cinder.



The following is an average analysis of the cinder experimented upon:—

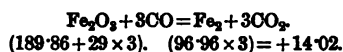
SiO <sub>2</sub> . . . . .	34.950
CaO . . . . .	27.865
MgO . . . . .	15.909
MnO . . . . .	1.176
CaS . . . . .	6.031
FeO . . . . .	0.810
Al <sub>2</sub> O <sub>3</sub> . . . . .	11.365
Na <sub>2</sub> O and K <sub>2</sub> O &c. . . . .	1.894
	<u>100.000</u>

The loss due to the heat carried off by the tuyeres and coolers was estimated by the exact quantity of water passing through them, multiplied by the temperature and the specific heat, by an average of a great number of experiments. At the foot of each column is given the total quantity of calories, also cwts. of coke and cost in shillings per ton of pig iron. In Column I. it will be seen that the heat units, developed by the combustion of 1.285 units of carbon when using 1.46 units of coke, give a total of 10382.8 calories, so that to get a constant value for each particular part of the process we have only to adopt the following formula, thus: in the case of the reduction of iron oxide, we require 3.912 cwts. of coke containing 88 per cent. of fixed carbon =  $\frac{1391 \times 29.2}{10382.8} = 3.912$ , and in a similar manner to get the actual cost of each part of the process. In Column II. it will be seen that out of 29.2 cwts. of coke we actually lost  $15.312 + 2.164 = 17.476$  cwts. of coke actually carried off by the combustible matter and sensible heat in the gases as they leave the throat of the furnace, leaving for the remainder of the process  $11.724$  cwts. of coke plus the heat brought in by the hot-blast, which gives a total of  $11.724 + 2.075 = 13.799$  cwts. of coke, required for internal purposes under the working condition previously mentioned. A careful examination of the figures given in the previous table will give an idea as to what particular part of the system we can expect to realise a saving as far as fuel consumption is concerned. In the first place, it will be seen that the reduction of the oxide of the iron per unit of pig, and the reduction of silicon, phosphorus, sulphur, manganese, and carbon taken up by the iron, also the fusion of the pig

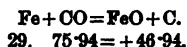
iron itself, requires a constant quantity of carbon in the form of coke, &c., which corresponds in the second column to 6·646 cwts. of coke, so that no matter what conditions of working, whether in charcoal or coke furnaces, we must attribute a definite weight of fuel to these parts of the system (assuming that the iron produced has the same composition); therefore we cannot expect to look for economy in this respect under any conditions whatever. On the other hand, all the other figures representing the remaining parts of the process are subject to alteration according to the mode of manufacture; take for example the difference in the speed of working the furnace by the application of brute force, it will readily be seen that we get a direct saving of fuel which would otherwise be lost by the radiation of heat from the furnace, and the cooling of the tuyeres and coolers, which saving is practically in proportion to the rate of driving, assuming that we are dealing with furnaces of the same external area and thickness of linings; or, in other words, the material in the furnace is insulated to the same degree from the atmosphere, and at the same time having the same quantity of tuyeres and coolers of a given area. In this particular case we have a furnace only making 78·23 tons per day, and the amount of coke actually wasted by radiation, &c., per ton of pig is 2·285 cwts.; by increasing the speed of working, say up to 469·38 tons per day, or six times the speed of the furnace under examination, we shall have a saving of 1·817 cwts. of coke, and the total loss in this respect would only be 0·368 cwts. instead of 2·285 cwts. The most particular points in the form of loss that require our special attention from a thermo-chemical standpoint are the following, namely, the loss due to the combustible matter in the escaping gases, which, in this particular case, evolves with the gases when leaving the furnace 15·312 cwts. of coke, which is equal to 12·248 shillings per ton of pig; this item alone is more than one-half the heat appropriated to the system. Then comes the fusion of the slag, representing 1·542 cwts. of coke, and the sensible heat carried off by the gases, which accounts for 2·164 cwts., also the expulsion of carbonic acid gas from the flux stone, and calcium as sulphide in the slag, together with the decomposition of the water vapour in the blast, all of which

represents a total of 19·84 cwts. of coke which cannot be directly accounted for as in the case of the previous examples, and it is quite evident that the various chemical and physical changes that govern the fuel consumption in the items just given, require a great deal of investigation before these very complicated problems are thoroughly solved; nevertheless, it can be shown to a certain extent how every one of the items, by rapid driving and an increase in the blast temperature, would effect a great saving; for example, one would naturally ask how we could expect to get a reduction in the temperature of the escaping gases by increasing the temperature of the blast, and consequently the temperature of the hearth, especially in the immediate neighbourhood of the tuyeres. As already explained, by increasing the temperature of the hearth, less blast per unit of iron made is required, for the reason that the oxides that are endothermic under ordinary conditions are converted into exothermic bodies, which is in part due to the heat absorbed by the materials on their descent to the hearth, with the result that a great amount of carbon is gasified in the hearth and bosh from the oxygen from these bodies, and therefore less nitrogen per unit of oxygen would be present in the furnace gases, and also a less quantity of water vapour would have to be decomposed at the tuyeres. By this it will also be seen that less gas per unit of material entering the furnace will be required, which simply means a larger quantity of cold materials entering the mouth, with a corresponding reduction of gases; this of course will readily explain the reason for a reduction in the temperature of the escaping gases; this alone will have a considerable influence on the 2·164 cwts. of coke shown by the table in Column II. Then comes the question of a reduction of the temperature in the gases due to rapid driving. This can be explained in a similar manner to the hot-blast question, only in this case we can account for the extra heat accumulated in the hearth as due to less heat per unit of iron being lost by radiation; or, in other words, extra heat is absorbed by the descending materials that would otherwise be lost by slow driving with an increased loss by radiation, &c., which will hereafter be more particularly described when dealing with the reducing zone of the ordinary furnace. Now comes that very important

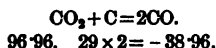
question of combustible matter in the gases which is shown in the table to represent 15·312 cwts. of coke. This particular question opens out a very large field for future research in thermo-chemistry, which will obviously, when thoroughly understood, lead to great economy in fuel consumption of blast-furnace practice; nevertheless, from a practical point of view, I feel convinced that rapid driving increases the quantity of carbonic acid gas in the gases when leaving the furnace, which points to the fact that a rapid transfer from the reducing zone to the hearth, of the reduced iron and other materials, would result in economy in this direction, on condition that the carbon and fluxes, &c., are heated sufficiently before approaching the hearth. Although in this case we are using a certain amount of forge or mill cinder, which is not reduced in that particular zone where ferric and to a less extent magnetic oxides are reduced, we have previously seen that hot-blast and rapid driving have an influence on the temperature of the escaping gases, &c., so that under these circumstances the reducing and carbon precipitation zone are placed under more favourable conditions, inasmuch as both reactions are exothermic, thus:—



We have a plus value of 14·02 for the reduction of ferric oxide by carbonic oxide, and for the precipitation of carbon by the reaction of metallic iron on carbon monoxide we get an exothermic value of 46·94, thus:—



And therefore we require no external heat to produce these chemical changes after chemical action has once started. It is quite probable that a great portion of the precipitated carbon, in the case of slow driving, would, on account of being in a nascent condition when just released from the monoxide, readily combine with the carbonic acid gas with which it would come in contact to form carbon monoxide. This reaction, which has an endothermic value of 38·96, thus:—



would continue until a great amount of the excess of heat

evolved by the previous reaction had been absorbed, or, in other words, a state of thermo-chemical equilibrium had been established, which would naturally be governed by the temperature, pressure, and general conditions of the mass of the materials in this particular zone. It will clearly be seen that once we can account for a saving of fuel in one particular case, there will be established a foundation that will lead to economy in every other part of the system, other than those cases previously mentioned. From time to time many authors have attempted to explain theoretically the reason why a charcoal furnace has more carbonic acid gas in the gases, and at the same time a reduction of temperature as compared with the ordinary coke furnace, but up to the present they have not arrived at a satisfactory solution, chiefly owing to the fact that charcoal is more readily attacked by carbonic acid than coke would be. In the blast-furnace we are confronted with that very important question known to thermal chemists as the influence of mass, and this is the question to my mind that will greatly assist us to decide the great difference between charcoal and coke furnaces. At a first glance it might be suggested, owing to the excessive volume occupied in the charcoal furnace by the fuel, that this would increase the possibility of dissolving the carbonic acid into carbon-monoxide, but of course we must take into consideration the properties of other materials; for example, we must consider the two very important reactions that take place in the reducing zone, namely, the reduction of iron oxides, and the splitting up of carbon monoxide by metallic iron as previously mentioned; both reactions, which are highly exothermic, develop a great amount of heat during the chemical changes. In the charcoal furnace it will be seen that the quantity of oxides of iron present in proportion to the gases is very small as compared with that of the coke furnace, owing to the excessive volume occupied by the charcoal, consequently less heat is evolved in a given quantity of matter, and at the same time a greater heating surface is exposed by the charcoal for the rapid absorption of the heat from the gases where reduction takes place, so that we have a less chance of bringing the temperature of the reducing zone to that point which would decompose the carbonic acid gas generated, owing to the fact that the decomposition of  $\text{CO}_2$  on

solid carbon or metallic iron is accompanied by absorption of heat, which indicates that any of these changes could only take place with the introduction of excess of external heat to the system; and again, it will be realised, the importance of the rapid transference of the reduced iron to the melting zone, consequently that equilibrium of chemical affinity which is established in an ordinary coke furnace is quite different to that in the charcoal furnace. There is another very important point that I wish to mention in favour of charcoal for keeping the temperature down when working under ordinary conditions; as a matter of fact charcoal has a higher specific heat than any other form of carbon used for furnace practice. Some of the different modifications of carbon compared with charcoal may approximately be represented as follows:—

Specific Heat Estimated by Newth at 45° C.		Specific Heat Estimated by Author at 100° C.	
Diamond . . . .	0·147	Durham Coppée coke .	0·231
Graphite . . . .	0·200	N. Stafford beehive coke .	0·246
Charcoal . . . .	0·241	Charcoal . . . .	0·275

By this it will be seen that charcoal absorbs an amount of extra heat from the reducing zone greater than would be the case with any form of carbon, which would again return to the hearth or bosh where it is required to deal with the residual oxides of iron and metalloids. There is also another very remarkable property of charcoal which is due to the possibility of various varieties, whereby it exposes a very large surface for the absorption of various gases, such as those gases that are the most readily liquefiable, for instance, ammonia gas; there is no doubt that the expulsion of this gas would absorb a large amount of heat in the lower part of the reducing zone, which is partially due to its decomposition into nitrogen and hydrogen. It may be, that owing to the comparatively low temperature in the reducing zone of the charcoal furnace, a portion of the nascent hydrogen given off from the fuel would to a certain extent prevent the action of carbonic acid gas on the carbon, and at the same time act as a reducing agent on the oxides of iron; on the other hand, any hydrogen that has been liberated from the moisture taken in by the blast, would not act as a reducing agent, as previously suggested by Sir Lowthian Bell;

it may be mentioned that the heat formation of hydrogen on the oxides of iron is endothermic. It is quite evident from what has just been mentioned that the ratio of carbonic acid gas to carbonic oxide in the escaping gases is entirely dependent upon the combined physical and chemical properties of the materials undergoing chemical change.

Although I have endeavoured to explain the reason of excess of carbon dioxide in the gases from a charcoal furnace, more than what might be expected from a coke furnace, I do not wish it to be understood that the charcoal furnace is the ideal furnace, as far as the ratio of carbon dioxide to carbon monoxide is concerned, for it is quite certain, that if we would reduce oxides of iron without being mixed with carbon, we should have better results as far as the ratio of the gases is concerned, and to prove this for my own satisfaction I conducted several experiments with purple ore in a small cupola. In these experiments I first of all introduced 1 cwt. of coke into the bottom of the cupola, which was allowed slowly to come to a red heat; then I suddenly added to this 10 cwts. of dry purple ore, and then applied a steady blast which was heated to about 500° C., when I arrived at the following results:—

Time of Experiment.	CO per Cent. by Volume.	CO <sub>2</sub> per Cent. by Volume.	Temperature of Gases.	Ratio $\frac{\text{CO}_2}{\text{CO}}$
6:37 P.M.	not taken	not taken	135° C.	
7:15 "	12	19	271° C.	1.58
7:40 "	16	22.6	339° C.	1.41
8:0 "	10.7	19.4	582° C.	1.81
	addition of fresh ore.			
8:40 "	7.6	35.2	221° C.	4.63
9:0 "	8	70	360° C.	8.75
9:15 "	6.2	23	482° C.	3.549

The best result as far as  $\frac{\text{CO}_2}{\text{CO}}$  is concerned was at a temperature of 360° C., which occurred twenty minutes after an addition of fresh ore was added. In my concluding remarks I have not thought it necessary at present to go thoroughly into detail with these experiments, but it is my intention still to prosecute further research on the thermal efficiency of the blast-furnace.

## APPENDIX

*Showing the System adopted for estimating the Value of the  
Different Parts of the Process.*

The average air blown into the furnace per day, after allowing for stoppages and leaks, &c., was found to be 14,491,380 cubic feet; the loss due to clearance, &c., in blowing cylinder and leakage to the furnace, was found to be 36·844 per cent.

Oxygen required to oxydise one unit of carbon to CO at the tuyeres

$$= 12 : 16 :: 1 : 1.33.$$

Composition of the atmosphere by weight, estimated at 0° C. and 760 mm.

= Nitrogen . . . .	76.02	per cent.
= Oxygen . . . .	23.07	"
= Hydrogen . . . .	0.098	"
= Carbon . . . .	0.0014	"

Air per unit of carbon burnt at the tuyeres at 0° C. and 760 mm. and 15° C. and 760 mm. respectively

$$= 23.87 : 100 :: 1.33 : 5.571 \text{ taken in grammes.}$$

$$\therefore \frac{36.87 \times 273}{273 + 15} = 34.049 \text{ grammes.}$$

Carbon oxydised by one cubic foot of air at 15° C. to CO

$$= \frac{34.949}{5.571} = 6.272 \text{ grammes.}$$

Weight in kilogrammes of carbon oxydised at tuyeres per day

$$= \frac{14,491,380 \times 6.272}{1000} = 90,889.9.$$

Tons of carbon oxydised per day

$$= \frac{90889.8 \times 2.2}{2240} = 89.3 \text{ tons.}$$

Air blown into the furnace per day

$$= \frac{89.3 \times 16 \times 100}{12 \times 23.87} = 498.8.$$



Quantity of each element blown into furnace per day estimated in tons

100 : 23·8731 :: 498·8 : 119·0792	of oxygen.
100 : 76·0275 :: 498·8 : 379·22517	of nitrogen.
100 : 0·098 :: 498·8 : 48882	of hydrogen.
100 : 0·0014 :: 498·8 : 00698	of carbon.
<u>100·0000</u>	<u>498·79947</u>

Carbon available for oxidation, after allowing for that taken up by the pig iron, &c.

Average make of iron 78·23 tons, coke per day = 114·24 tons  
coke per ton of iron, 1·46 tons.

Average analysis of coke—

Fixed carbon	=	88
Sulphur	=	1
Ash	=	10
Moisture	=	1
Total	=	<u>100</u>

Pure carbon per day

$$= \frac{114 \cdot 24 \times 88}{100} = 100 \cdot 53.$$

Average analysis of part mine pig during time covered by experiments—

		Metalloids absorbed per Unit of Pig.
Carbon . . .	3·5 per cent.	= 0·035
Silicon . . .	3·25 "	= 0·0325
Phosphorus . .	1·49 "	= 0·0149
Sulphur . . .	0·03 "	= 0·0003
Manganese . .	1·05 "	= 0·0105

Tons taken up per day—

Carbon	= $\frac{78 \cdot 23 \times 3 \cdot 1}{100}$	= 2·738 tons.
Silicon	= $\frac{78 \cdot 23 \times 3 \cdot 25}{100}$	= 2·54247 tons.
Phosphorus	= $\frac{78 \cdot 23 \times 1 \cdot 49}{100}$	= 1·1656 tons.
Sulphur	= $\frac{78 \cdot 23 \times 0 \cdot 03}{108}$	= 0·02347 ton.
Manganese	= $\frac{78 \cdot 23 \times 1 \cdot 05}{100}$	= 0·821415 ton.
Pure iron	= $\frac{78 \cdot 23 \times 90 \cdot 68}{100}$	= 70·9389 tons.

Oxygen introduced into the furnace by the materials calculated from the pig iron and metalloids, together with the oxygen from the calcium and manganese existing as sulphides in the slag, tons per day—

$$\text{Si} + \text{O}_2 = \text{SiO}_2 = \frac{32 \times 2.5425}{28} = 2.905 \text{ tons.}$$

$$\text{P}_2 + \text{O}_5 = \text{P}_2\text{O}_5 = \frac{80 \times 1.1656}{62} = 1.504 \text{ tons.}$$

$$\text{S} + \text{O}_2 = \text{SO}_2 = \frac{32 \times 0.2347}{23} = 0.02347 \text{ ton.}$$

$$\text{Mn}_3 + \text{O}_4 = \text{Mn}_3\text{O}_4 = \frac{64 \times 0.821415}{165} = 0.3186 \text{ ton.}$$

The oxygen given off by 70.9389 tons of iron as pig iron is taken from an average mixture of the charge; the rates of iron to oxygen

$$= 53.57 : 17.4$$

$$\therefore \text{tons of oxygen per day} = \frac{70.9389 \times 17.4}{53.57} = 230.41.$$

Oxygen due to sulphides of manganese and calcium in the slag sulphur found in slag = 2.747 per cent., which is equivalent to 1.373 of oxygen.

$$\therefore \frac{1.373 \times 87.561}{100} = 1.201.$$

Total oxygen per day—

		Tons,
Oxygen introduced by air	.	119.079
"	" silica	2.905
"	" phosphoric acid	1.504
"	" sulphur as dioxide	0.023
"	" manganese	0.319
"	" calcium, &c., in slag	1.201
"	" iron oxides	23.041
Total		<u>148.072</u>

$$\text{Slag per ton of pig} = \frac{87.561}{78.23} = 1.119.$$

Fixed matter in flux (dolomite) = 53 per cent.

$$\begin{aligned} \text{" carbonic acid} & \quad . \quad . \quad = 46 \quad \text{"} \\ \text{" moisture} & \quad . \quad . \quad = 1 \end{aligned}$$

Iron producing materials per day = 133·15 tons, together with 2·5298 of moisture.

Carbonic acid from flux	$= \frac{50·597 \times 46}{100}$	$= 23·274$
Moisture	$= \frac{50·597 \times 1}{100}$	$= 0·506$
Fixed matter	$= \frac{50·597 \times 53}{100}$	$= 26·817$
Dolomite per day	$= \frac{133·15 \times 38\%}{100}$	$= \underline{\underline{50·597}}$

Estimation of slag per day—

Mineral entering furnace	$= 133·15$ tons.
Fixed matter in dolomite	$= 26·817$ „
10 per cent. ash in coke	$= 11·424$ „
	$\underline{\quad\quad\quad}$
	171·391 „

Deduct from materials entering the furnace the oxygen from metalloids, also that from the calcium and manganese in the slag; in this case the small quantity of dust in gases is estimated as slag.

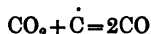
171·391 less pig iron and oxygen from metalloids, &c.

$$= 171·391 - 83·83 = 87·561 \text{ tons.}$$

Estimation of gases—

Moisture from coke	$= 1·1424$ tons per day.
„ „ dolomite	$= 0·506$ „ „
„ „ mineral	$= 2·5298$ „ „

Carbon assumed to be gasified by the expulsion of  $\text{CO}_2$  from flue, according to equation—



$$44 : 12 :: 23·274 : 6·347 \text{ tons.}$$

$$\text{Total gas from reaction} = 23·274 + 6·347 = 29·621.$$

Carbon passing through furnace for oxidation in the hearth, &c.

$$= 100·53 - (6·347 + 2·728) = 91·445 \text{ tons.}$$

Carbon gasified to carbon monoxide in lower part of furnace—

$$\text{Oxygen required} = 91·445 \times 1·3 = 121·896.$$

$$\text{Oxygen entering furnace at tuyeres} = 119·079.$$

$$\text{Deficiency} = \text{excess of carbon} = 121·896 - 119·079 = 2·817.$$

Total weight of gases—

Oxygen from blast	= 119·079 tons.
„ due to S in pig	= 2·905 „
„ „ $P_2O_5$	= 1·504 „
„ „ S in slag	= 0·023 „
„ „ $Mn_2O_4$	= 0·319 „
„ „ FeO and $Fe_2O_3$	= 23·041 „
„ „ Ca and Mn in slag	= 0·849 „
„ „ $Co_2$ in dolomite	= 16·927 „
Total	<u>164·647 „</u>

Carbon in gases—

C in blast as $CO_2$	= 0·007 tons
C introduced less than	97·802 „ in pig iron
C from flux	= 6·346 „
Total	<u>104·155 „</u>

Other gases—

H in blast	= 0·4890 tons.
N „	= 379·2250 „
$H_2O$ in coke	= 1·1424 „
„ „ dolomite	= 0·5060 „
„ „ mineral	= 2·5293 „
Total	<u>382·8922 „</u>

Grand total = 652·6942 tons per day.

Estimation of the ratio between the carbon oxides. Oxygen required to oxydise C to CO—

$$\begin{aligned}
 &C + O = CO \\
 &12 + 16 = 28 \\
 &12 : 16 :: 104·155 : 138·873. \\
 &\text{Total CO and } CO_2 = 104·155 + 164·647 = 268·802 \text{ tons.} \\
 &\text{Excess of oxygen} = 164·647 - 138·873 = 25·774. \\
 &CO_2 \text{ in the gases} = O + CO = CO_2 \\
 &16 + 28 = 44. \\
 &16 : 44 :: 25·774 : 70·878 \\
 &CO = 268·802 - 70·878 = 197·924. \\
 &\therefore CO = 197·924 \text{ tons.} \\
 &CO_2 = 70·878 „ \\
 &\text{Total} = 268·802 „
 \end{aligned}$$

$CO_2$  other than accounted for from dolomite  
 = 70·878 - 23·274 = 47·604.

Gases to account for heat generated

$$= 197\cdot924 \text{ CO.}$$

$$47\cdot604 \text{ CO}_2.$$

Oxides of carbon per ton of pig from carbon added to the charge—

$$\text{CO} = \frac{197\cdot924}{78\cdot23} = 2\cdot53 \text{ tons.}$$

$$\text{CO}_2 = \frac{47\cdot604}{78\cdot23} = \cdot6085 \text{ „}$$

Carbon per ton of pig in CO = 28 : 2·53 :: 12 : 1·084.

Carbon per ton of pig in CO<sub>2</sub> = 44 : ·6085 :: 12 : 166.

Total combustible carbon = 1·25.

Ratio of the total carbon in the gases, including that from flux, estimated as  $\frac{\text{CO}_2}{\text{CO}}$ .

$$\text{Including carbon from flux} = \frac{24709}{1\cdot084} = 2279.$$

$$\text{Not including carbon from the flux} = \frac{166}{1\cdot084} = 0\cdot1531.$$

The calorific values were estimated in the usual way.

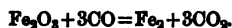
## CORRESPONDENCE.

Mr. WELDON HANSON (Stockton-on-Tees), commenting upon Mr. Foster's statement that rapid driving increases the quantity of carbonic anhydride in the gases leaving the furnace, says that at the Clarence Iron Works he (Mr. Hanson) has analysed the gases from furnaces, the "make" of which has been gradually increased from 600 to 1300 tons per week, but the ratio of carbonic anhydride to carbonic oxide, instead of going up, has gone down. With 600 tons per week the ratio was usually 0·60 to 0·65; with 1300 tons per week it is 0·45 to 0·50. Attached to one of the furnaces is a Uehling's composimeter, which estimates the volume of carbonic anhydride in the escaping gases continuously. On turning on blast after a stand, the apparatus shows almost invariably a momentary increase in carbonic acid. This led him to make a complete analysis of the gases coming off the furnace when it was working with a natural draught, that is, no blast on, tuyeres open, and burner open at top. The draught at tuyeres was 1 inch water. This may be considered, he thinks, the slowest possible driving. The gases coming off consisted of:—

	Volume.	Weight.
CO <sub>2</sub> . . . . .	29·7	41·3
CO . . . . .	46·0	40·8
H . . . . .	4·3	0·3
N . . . . .	20·0	17·6
	<hr/> 100·0	<hr/> 100·0

$$\text{Ratio of } \frac{\text{CO}_2}{\text{CO}} = 1·01.$$

The composimeter does not show such a high percentage of CO<sub>2</sub> as is given here, but owing to the position of the instrument it only gets a whiff of this gas when the blast is put on. This analysis, coupled with his fast-driving experience, shows that the slower the gases pass through the furnace the better the reaction.



Professor A. LODIN (Paris) writes that the data contained in Mr. Foster's paper are very interesting, inasmuch as there is in the technical literature some deficiency of information upon the points dealt with. It is to be regretted only that the composition

of the ore charge and of the escaping gases have not been given exactly.

The theory prepared by the author in order to explain the efficiency of the hot blast by the partial dissociation of the water molecule before entering the furnace is inconsistent with the most recent laboratory experiments upon the question. According to Mallard and Le Chatelier, water does not show the least symptom of dissociation at temperatures over  $3000^{\circ}\text{C}.$ ; still less at the usual temperature of the hot blast.

The true explanation of the efficiency of the additional calories brought by the hot blast is to be found in the elevation of the temperature of combustion of solid carbon in the hearth. In this zone of the blast-furnace, there are to be taken into account only calories available at a high temperature, surpassing the melting-point of pig iron and slags, or the point of reduction of manganese, phosphorus, and silicon. We cannot give here full developments upon this fundamental principle, but the correctness of the same is illustrated by the blast-furnace practice in old and recent times. The temperature of combustion of solid carbon by cold air, such as takes place in the hearth of ancient blast-furnaces, exceeds hardly  $1400^{\circ}\text{C}.$ , when calculated with accurate values of the specific heat of gases. It is inferior to the melting-point of the basic slags connected with the production of high-grade alloys of iron with manganese or silicon. It is the reason why the production of such alloys, unknown to ancient metallurgists, was made possible by the use of over-heated blast.

Mr. JOHN PARRY (Ebbw Vale) sends particulars showing the system adopted by him as the results of careful studies of the researches of Sir Lowthian Bell and Professor Gruner. He had found it impossible to give a balance-sheet of the products from the blast-furnace, which, though complete, were beyond the limits, and too elaborate for the practical reports asked for by those to whom he had had to report. Therefore he had directed his attention to the framing of a report, which, while as simple as possible, was yet practically useful, and which was periodically compared with the usual commercial statements sent to the office.

Table I. is the first form, giving details.

Table II. is a simple form of above, which could be readily understood by the furnace manager and general staff of employees. They had been allowed 10 per cent. loss throughout the year on their coke. This had been found ample to compensate for all possible loss.

TABLE I.—*Composition of Ores, Fuel, &c.*

	Ore.	Coke.	Limestone.
Iron . . .	54.26 per cent.	...	...
Oxygen . . .	21.82 "	...	...
Silica, &c. . .	13.92 "	10.00	5.00
Water, &c. . .	10.00 "	10.00	3.00
Carbon . . .	...	80.00 (CO <sub>2</sub> )	40.50
Lime . . .	...	...	51.50

*Distribution of Materials.*

Pig iron . . . . .	1.000
Gases (O from ores 0.39; H <sub>2</sub> O, 0.419; CO <sub>2</sub> , 1.064) . . . . .	1.873
Slag (lime, silica, &c., ash in coke) . . . . .	0.493
	<u>3.366</u>

*Average Composition of Waste Gases.*

Carbonic anhydride, 14.06; carbonic oxide, 36.9; ratio, 0.381.

*Gases per 1 Ton of Pig Iron produced.*

Carbonic Anhydride.	Carbonic Oxide.	Blast.
0.7605	2.1129	6.10

*Temperature of Blast, 700° (average).*

Estimated heat required for smelting ores, &c. . . . .	3694
6.1 + 353 × .239. Deduct heat of blast . . . . .	414
	<u>3280</u>

Carbon used  $1.068 \times 8060 = \frac{8608}{1} = \text{ratio} = \underline{0.38}$

TABLE II.

Average composition of ores . . . . .	{	Silica, &c.	13.29
		Iron . . .	50.20
		Oxygen . . .	21.51
		Water, &c.	15.00
Pig iron per cent. on total materials used . . . . .	{	Pig iron . . .	53.40
			<u>29.21</u>
Materials used per ton of pig iron made . . . . .	{	Ore . . .	1.873
		Coke . . .	1.166
		Limestone . . .	0.304
			<u>3.343</u>
Distribution of materials . . . . .	{	Pig iron . . .	1.000
		Gas . . .	1.810
		Slag . . .	0.533
			<u>3.343</u>



Mr. FOSTER in his reply referred to the remarks made by Mr. Hanson on the decrease in the ratio of carbon dioxide to carbon monoxide, which he found was due to an increase in the rate of driving, and stated he was afraid that Mr. Hanson had not grasped the true nature of his statement. As regarded his experiments at the Clarence Works, he did not for a moment disagree with his remarks, namely, that the ratio had fallen 0.15 by increasing the driving from 600 to 1300 tons per week, but those conditions as a general rule were abnormal, and it was quite evident that under those circumstances any practical furnace-man would at once come to the conclusion that there was something radically wrong with the furnace or some other part of the system. Take the furnace, for example: it was quite common knowledge that reducing the rate of driving after it had been working regularly for some time would increase the quantity of carbon dioxide, but this state of things could not last for an indefinite period, or, in other words, the ratio would soon reach its normal position, and ultimately a decrease in the ratio of  $\text{CO}_2$  to  $\text{CO}$  would appear when the furnace had gradually settled down to its new working conditions, assuming that other conditions were equal to the occasion. The same thing would occur, but in the reverse order, by an increased rate of driving, consequently it would be seen that an interruption in the rate of driving would create false conditions.

To illustrate the peculiar characteristics of a furnace, take for example a case where a furnace was working under normal conditions, and the slag suddenly became dark in colour, and at this stage the rate of driving was considerably reduced. It would be seen that this furnace under ordinary circumstances would throw a grey cinder; and sometimes this change was very sudden, but the condition, as he had explained in his paper of May 1902, was only one of many complicated problems, the nature of which could only be ascertained by indirect reasoning, otherwise it would lead to the conclusion that this practice would be economical as far as fuel consumption was concerned. He contended that conditions of an abnormal character were also brought about in the case of the composition of the gases, therefore he could only confirm his previous statement, namely, that rapid driving with a plant properly equipped would lead to

economy in fuel, which could not be the case cited by Mr. Hanson, if ascertained directly, owing to such a large reduction in the ratio of carbon dioxide to carbon monoxide found in the escaping gases at the time of experiment. The results of Mr. Hanson's experiments confirmed his own experience from several experiments taken under different circumstances.

He was rather surprised to see that Mr. Lodian had raised an objection to the deficiency in the technical literature, without giving particulars in detail. As far as his (Mr. Foster's) knowledge was concerned, he had not omitted any item either in the ore charge or the escaping gases that would in any way interfere with the general principle of estimating the thermal efficiency of the blast-furnace. He was not aware that it was necessary to give the name of any particular material used as long as the average chemical composition was known; his only regret was the want of a thorough knowledge of the combined chemical and physical properties of all the matter involved in the process, which would require very careful investigation in the future, and it was for this reason that a true formula had not been previously advanced, giving the true nature of the hot-blast question.

Referring to the partial decomposition of the water molecule, it was quite certain that an increase in the temperature could be got up to a certain point, without any free hydrogen or oxygen being liberated under certain conditions, but at the same time the heat absorbed or stored by the molecule was constant, and was held latent, until the temperature and other conditions were sufficient to completely decompose the molecule into its constituent elements.

Partial decomposition was also constant without the action of an intermediate chemical body, which might be brought about by the action of an intermediate agent, such, for example, as electrical energy. It was quite certain that the complete decomposition of the water molecule was brought about in the case of passing it through hot bricks or any other catalytic agent at a considerably lower temperature than  $3000^{\circ}\text{C}$ .

All that would be required to explain the effect of water on the hot-blast theory would only require a knowledge of the quantity of heat units absorbed by the molecule to allow for

decomposition equal to that evolved during the formation of the molecule, plus the heat required to bring the temperature of the liberated elements to that point that any resulting chemical or physical changes would not interfere with the existing average temperature of all matter in the hearth, where reduction on solid carbon was necessary.

He had already explained in his paper of May 1902 his views on the physical and chemical properties of solid carbon in the hearth of the blast-furnace, which, in his opinion, was essential to explain the hot-blast theory.

## THE PLASTIC YIELDING OF IRON AND STEEL.

By WALTER ROSENHAIN, B.A. (CANTAB.), B.O.E. (MELBOURNE), BIRMINGHAM.

IN the first number of the *Revue de Métallurgie*, Messrs. Osmond, Frémont, and Cartaud have published a paper on the "Modes of Deformation of Iron and Soft Steel,"\* dealing at some length with the microscopic effects of plastic strain upon these metals and with the interpretation of these effects. In the course of this paper they express disagreement with the conclusions arrived at by Professor Ewing and the present author,† as well as those of Ewing and Humfrey. It is particularly gratifying to find so eminent a metallographer as Mr. Osmond entering the field of physical metallography—a field which has not hitherto received the attention it deserves; and, so far from being indifferent to the views of the French authors or resenting the divergence of their opinions from his own, the present author has been led to re-examine the evidence upon which these views were originally based. The results of this examination, with the new developments arising from it, form the subject-matter of the present paper. For the sake of continuity and completeness of argument, it will be necessary to repeat here some portions of matter already published in previous papers. In order to avoid burdening the Journal of this Institute with micrographic illustrations which have already been reproduced, frequent references will be made to illustrations contained in other earlier publications.

The fundamental phenomenon upon which the views enunciated by Ewing and Rosenhain in Paper A are based, is the change in

\* Osmond, Frémont, and Cartaud, "Les Modes de Déformation et de Rupture des Fers et des Aciers Doux." *Revue de Métallurgie*, Paris, 1904.

† J. A. Ewing, F.R.S., and Walter Rosenhain, on "The Crystalline Structure of Metals," Bakerian Lecture, *Phil. Trans., Royal Soc.*, 1899, Series A, vol. cxciii. pp. 353-375—Paper A; and on "The Crystalline Structure of Metals," second paper, *ibid.*, vol. cxcv. pp. 279-301 (1900)—Paper B. J. A. Ewing, F.R.S., and J. C. W. Humfrey, B.A., "The Fracture of Metals under Repeated Alterations of Stress," *Phil. Trans., Royal Soc.*, 1902, Series A, vol. cc. pp. 241-250—Paper C.

For convenience of reference, these papers will be referred to in the present paper by the letters indicated in this note.

appearance which may be observed when a previously polished and etched specimen of iron or other metal is plastically deformed and then again examined under the microscope. If the usual vertical illumination be used, the surface of the specimen, previous to straining, is seen to be divided into the well-known polygonal areas which mark the crystalline grains of the metal; after the application of force resulting in permanent deformation, however, the areas of the crystalline grains are seen to be cross-hatched with a number of fine black lines. These lines are seen to be in a general way parallel to one another within the area of each crystalline grain, but to have different directions in different grains. For the interpretation of this appearance it is necessary to consider the special character of the illumination which is employed. Under "vertical" light only horizontal, or nearly horizontal, surfaces will appear bright, since these alone can reflect light back into the objective of the microscope; any portions of the surface under examination which are steeply inclined to the horizontal will throw the light which reaches them from the objective away to one side, and will therefore appear dark to the observer. The black lines above described may therefore be accounted for by supposing that the effect of the plastic deformation has been to produce surface inequalities outlined by narrow inclined surfaces. So far as their appearance under vertical illumination is concerned, these inclined surfaces might consist either of slopes or steps having a definite inclination, or of indefinite rounded foldings. It is, however, possible to distinguish sharply between surface inequalities of these two classes by means of examination in oblique light, particularly if a parallel or nearly parallel beam be used. If the surface slopes be indefinite and rounded—in fact, curved folds—they will be able to reflect into the objective light coming from many directions in the same vertical plane, and the apparent width and position of the bright lines observed under these conditions would alter considerably with any alteration of the angle of incidence of the light. If, on the other hand, the surface inequalities in question are of the nature of definitely inclined and oriented slopes or steps, then each set of lines will reflect into the objective light of one particular angle of incidence only, and the bright lines thus observed will disappear sharply as the angle of inci-

dence of the light is altered—as, for instance, by rotating the stage of the microscope.

The diagrams, Figs. 1 and 2, illustrate these two cases in a diagrammatic, and of course grossly exaggerated, form. In Fig. 1, light, as indicated by the arrow heads, is supposed

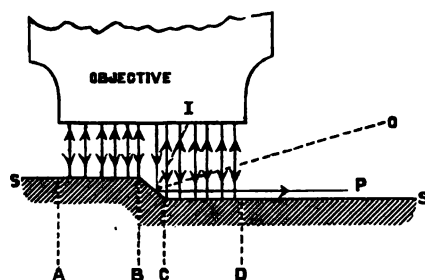


FIG. 1.

to fall vertically upon the surface under examination (SS) from the objective above it. Where the surface is horizontal, as at AB and CD, the reflected rays will return into the objective upon their paths; but where the surface, as at BC, is inclined to the horizontal, the reflected rays will be sent outward, as

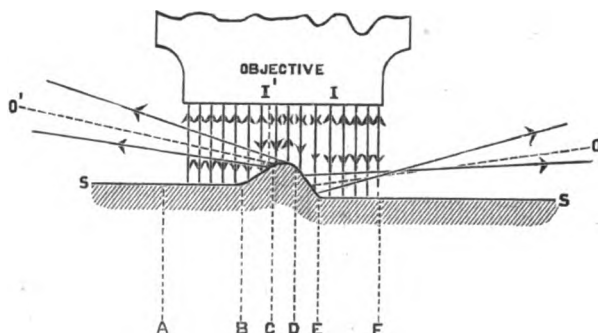


FIG. 2.

indicated by the arrow P. To the observer looking down the microscope, the portions AB and CD will therefore appear brightly illuminated, while the area BC will appear as a dark band. (The diagram is, of course, a section through the microscope and specimen, taken along the axis of the microscope.)

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Fig. 1 is thus a diagram of a slope or step in the surface having a definite angle and orientation. Fig. 2, on the other hand, is a diagram of a fold in the surface. Following the course of the reflected rays as sketched in the diagram, it will be seen that such portions of the surface as BC and DE would appear as dark bands under vertical illumination. The effect of oblique illumination is readily followed upon the diagrams by supposing light to start from such points as  $OO'$ . Where such light strikes the horizontal portions of the surface, it is obliquely reflected and does not reach the objective, but where the oblique beam strikes a surface of suitable inclination, the light may be so reflected as to enter the objective, and such parts of the surface will consequently appear bright upon a dark background. In Fig. 1 it is obvious that light from the direction of O will enter the objective, while light from a diametrically opposite point will not do so. In the case of Fig. 2, however, light from either O or  $O'$  will be reflected into the objective. If the surface inequalities were in the nature of folds they could only be thought of as having an "up" as well as a "down" slope, somewhat as indicated in Fig. 2; and from this consideration it would appear likely that under vertical light we should see pairs of black lines close together with a bright line between them (BC and DE, Fig. 2, black, CD bright) instead of the sharp single lines actually observed, and under oblique light the lines on the same crystal grain should appear bright under light incident at each of two directions 180 degrees apart. This latter point may be tested very beautifully by either rotating the stage of the microscope through 180 degrees from a position in which any set of lines appears bright, or by using two sources of light of different colour, such as white and red, placed 180 degrees apart. In either case it is abundantly clear that any set of lines appears bright in only one of two incidences of light 180 degrees apart.

Figs. 3 and 4 are photomicrographs \* of a specimen of strained iron taken to illustrate the observation here referred to. Both photographs are from the same microscopic field, and would appear identical if they had been taken with vertical light. In the actual photographs, the stage of the microscope has been

\* For details of magnifications, &c., of photomicrographs, see Appendix.

turned through an angle of 180 degrees between the two exposures. As reproduced, the photograph itself has been turned back



FIG. 3.

through the same angle, so that the two views of the same field are strictly comparable. The lines of deformation which are



FIG. 4.

brightly illuminated on the central crystal in the position of Fig. 3 are quite invisible when the incidence of the light is changed



by 180 degrees, while the lines on other crystals, not previously visible, are revealed in the position of Fig. 4. I consider that this evidence is conclusive proof that the surface inequalities produced by plastic strain are not rounded foldings, but sharply inclined and definitely oriented slopes or steps in the surface. I have attached special weight to the examination of the strained specimens in oblique light of various incidence, because Messrs. Osmond, Frémont, and Cartaud advance the view that the surface inequalities in question are of the nature of folds (*plissements*). Throughout the paper of the French authors, however, no mention is made of examination under oblique light, so that these authors have not only failed to establish their view by means of any novel evidence of this convincing kind, but they have absolutely ignored the evidence on these lines already adduced by Ewing and Rosenhain (Paper A).

Once the true physical character of the minute surface inequalities which result from plastic deformation is realised, the explanation of their occurrence advanced by Ewing and Rosenhain is almost inevitable. It is not necessary to recapitulate here, where the work of Stead\* is so well known, the evidence for believing that the crystalline grains of iron, which the microscope reveals as polygonal areas, are of the nature of true crystals, and that consequently each of these grains may be regarded as being built up of a very large number of similar and similarly oriented particles. Such a structure will possess cleavage and gliding planes similar to those found in other crystals, and according to the view of Ewing and Rosenhain, the plastic yielding of such crystals occurs by means of slips taking place along these cleavage or gliding planes. It may be considered that the piece of metal as a whole is constrained, by the external forces applied to it, to assume a shape different from that which it previously possessed, and to this new shape the individual crystalline grains must adapt themselves. According to the present view, they do so by the sliding of the crystalline elements over one another on at least three, and generally more than three, sets of gliding or cleavage planes. The actual slips which take place in any one crystalline grain will depend as much upon its

\* Stead, *Journal of the Iron and Steel Institute*, 1898, No. I. p. 145, "The Crystalline Structure of Iron and Steel."

immediate environment as upon the general character of the deformation produced; each crystal grain adapts itself to the requirements of its neighbours, but without any deformation of the elementary crystalline particles of which the crystals are built up. According to this view, Ewing and Rosenhain have called the black lines which appear after strain "slip-bands."

Before dealing in detail with the various lines of argument upon which Messrs. Osmond, Frémont, and Cartaud base their objection to the theory of the crystalline character of "slip-bands," I wish to dwell upon another line of evidence which strongly supports the view that these deformations are of a crystalline nature.

This evidence is obtained by the examination of specimens of iron or very mild steel which have been subjected to very severe plastic deformation, as by cold rolling, cold hammering or pressing, &c. In such specimens it is easy to recognise the fact that the various crystals have been severely deformed—if the section be so taken that the direction of the deformation lies in the plane of the surface, elongation of the crystal grains in one direction is very marked; and even if the section be taken transverse to the direction of the deformation the distorted outlines of the crystal grains are at once evident to an experienced eye. In all such cases, however, the metal is still quite as characteristically crystalline as in the normal state. The various crystal grains still show the same "oriented lustre" under oblique light as the etched crystals of normal metal, and the geometrical figures produced by etching, especially as shown by Heyn, with copper-ammonium chloride, still remain similar and similarly situated figures.\*

\* Allusion is made by Heyn and by Osmond, Frémont, and Cartaud to cases in which they have observed a change of orientation of the etched figure within the one crystalline grain after severe deformation, and Prof. Heyn has been kind enough to show me such a specimen. This is, however, no proof that the crystalline elements themselves have been deformed, as it would appear unlikely that if deformation took place at all, it would merely alter a rectangular figure into an oblique parallelogram. Further, the change can be accounted for on the hypothesis of slip without deformation, by supposing that in special cases the slip should partake of the nature of a rotation in the plane of sliding; this would result in a slight alteration of the angle at which the crystalline elements lie to the surface, and a slight change in the etched figures would result. From considerations to be advanced later, I regard it as likely that careful search will reveal similar slight variations of orientation within the crystalline grains of unstrained iron and steel.

Illustrations of the crystalline character of severely deformed iron have been given in Paper A, Figs. 31, 32, 33. A further illustration is given in Fig. 5, showing the oblique light appearance of a piece of Swedish iron which had been reduced to half its original thickness by hammering in the cold, the section being subsequently cut along the direction of the deformation; the elongated shapes of the grains and their uniform crystalline orientation is well shown. It appears to me that this line of evidence very strongly supports the view that plastic deformation occurs by crystalline slips; on that hypothesis alone is the crystalline character of deformed metal intelligible.

I will now take up the contentions advanced by Messrs. Osmond,

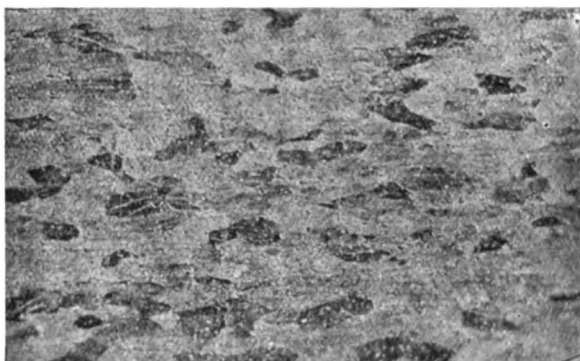


FIG. 5.

Frémont, and Cartaud. The first of these is that the slip-bands in iron cannot be crystalline in character, as they are not rectilinear. The view is evidently implied that crystallisation must necessarily be rectilinear, but such a view is by no means borne out by observation of admittedly crystalline substances. It is well known that under certain conditions of disturbance during the act of crystallisation, as for instance when it takes place in a viscous fluid or in a fluid in motion, ordinarily rectilinear crystals, such as those of felspar or ammonium chloride, become curved. It appears probable, however, that this curvature is only apparent, the curves being really made up of a very great number of small rectilinear steps, and I have obtained evidence tending to show that the curvature of slip-bands in iron and certain other metals

may be accounted for in the same way. On this view, the curved character of iron slip-bands when observed under moderate magnifications would be due to want of sufficient resolving power to reveal the minute rectilinear steps of which each apparent curve is made up. Evidence in support of this view is to be derived from the fact that in many cases the application of the highest available resolving power actually reveals the minute steps in a slip-band which, under lower magnification, appeared curved. Figs. 6 and 7, both taken from a mild steel at 1450 diameters, clearly show this stepping. Fig. 6 particularly strongly confirms the crystalline view of slip-bands. Fig. 8 is another example of the stepping across of a slip-band from one system of cleavage planes to another and back again.

Further evidence of the stepped character of apparently curved slip-bands is to be obtained by examination under oblique light, using as high a magnification as is available under those circumstances. Seen in this way, the slip-bands no longer appear as continuous curved lines, but are broken up into a great number of short lines, with short dark gaps between their ends. My interpretation of this appearance is that the small dark gaps seen in the slip-bands under these conditions represent the larger elements of the steps which give rise to the apparent curvature; these steps, being slips on another system of cleavage planes inclined at a different angle, send the light which is suited to the orientation of the main portion of the band away from the objective. Fig. 9 is a photomicrograph of slip-bands in iron under oblique light, showing the dotted line character very clearly; it should perhaps be observed that the slight blurring of the bands in the photograph is due to the diffraction patterns formed by the microscope, together with a certain amount of halation and diffusion of the image in the photographic plate.

If it be admitted, as I think, in view of the evidence just adduced, it must be, that the apparently curved character of slip-bands in iron and soft steel is in reality due to the frequent stepping across of slip-bands from one system of cleavage planes to another, it yet remains to be explained why this stepping across should occur so frequently in iron and so rarely in other metals, such as cast lead or copper, strained under similar conditions. I think the explanation is not very far to seek if we

consider under what circumstances the ferrite crystals as we see them in the microscope have been formed. In the case of

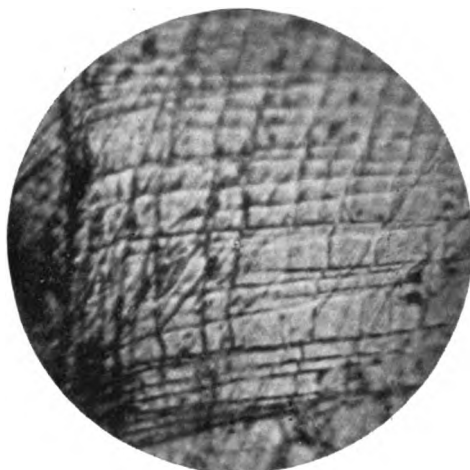


FIG. 6.

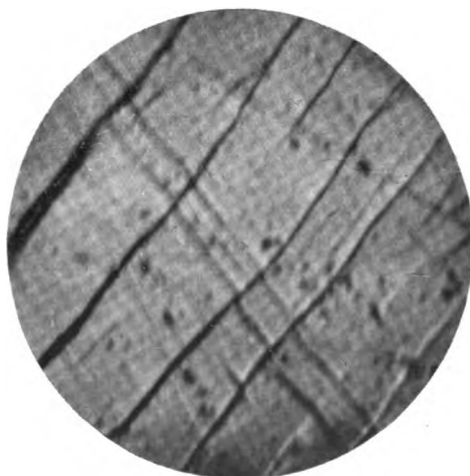


FIG. 7.

metals which show characteristically straight slip-bands, such as cast lead and copper, we are dealing with crystals which have

been formed by crystallisation from an actual fluid, and have remained unaltered since the initial freezing of the metal; in the

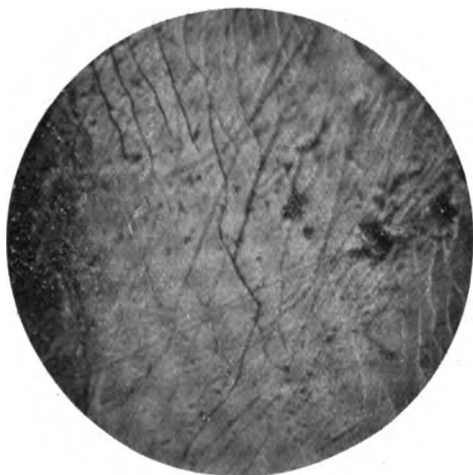


FIG. 8.

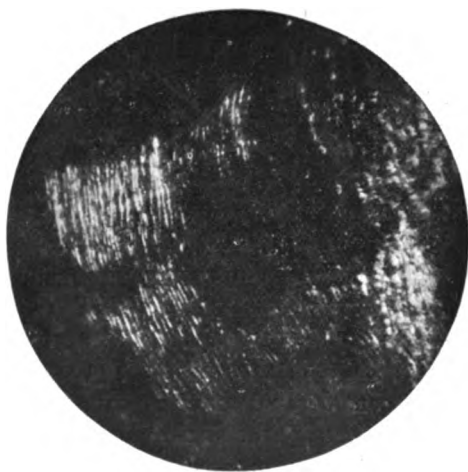


FIG. 9.

case of ferrite, however, we are dealing with crystals which have formed in a *solid* on passing a certain critical range,

and we are thus dealing with crystallisation under very considerable difficulties. As has already been pointed out, if crystallisation of an ordinary salt be hindered or rendered difficult, the crystalline growth becomes distorted and greatly stepped forms result. Now it is very probable that the surfaces of least resistance to cleavage or slip in any crystal will to some extent follow the surfaces of growth in the crystal, so that in a crystal which has been forced to develop in a tortuous manner we may expect to find greatly stepped and tortuous slip-bands. Several ways of testing this explanation have suggested themselves to me, but the only one I have so far been able to carry out is the following. As has already been stated, the slip-bands in cast lead are characteristically straight; Fig. 10 is a photomicrograph of slip-bands in cast lead. Now it has been shown (Ewing and Rosenhain, Paper B) that by first very severely deforming a piece of lead, and then very slightly warming it, the metal may be made to recrystallise. As the large crystals of lead produced in this way have also been formed by crystallisation in a solid, if the view of the origin of "curved" slip-bands in iron which I have advanced above be correct, then these lead crystals should also show "curved" slip-bands. The experiment was carried out by first crushing a small cast ingot of lead into a flat sheet; from this sheet a strip about half an inch wide was cut, and a small area of the strip scraped clean and then immediately pressed with considerable force against the polished face of a large block of glass. In this way a very perfect mirror-like surface was obtained. The entire strip was then sealed up in a glass tube and placed in an oven kept at  $200^{\circ}$  C. for several hours. The specimen was then removed from the tube and slightly bent with the fingers so as to develop the slip-bands. The entire structure was clearly developed in this way, and it was evident from the scale of this structure that the process of recrystallisation had gone on to a very considerable extent. Figs. 11 and 12 show characteristic forms taken by the slip-bands on specimens treated in this way; they differ very markedly from the straight regular lines seen in the cast metal, and approximate very closely to the character of the slip-bands in iron, as illustrated by Fig. 13. It is evident, therefore, that the character of the slip-bands is very largely dependent upon the conditions under which the

crystals of a given sample of metal have been formed. We have here a principle which by further working out may become

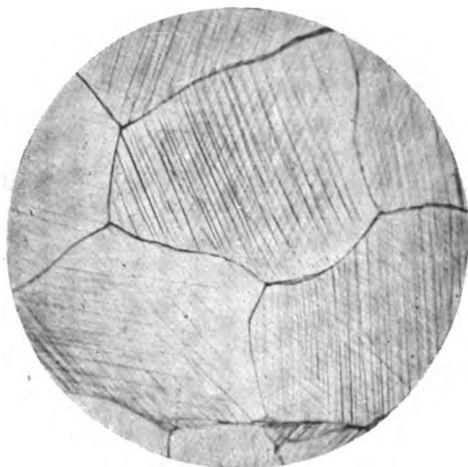


FIG. 10.

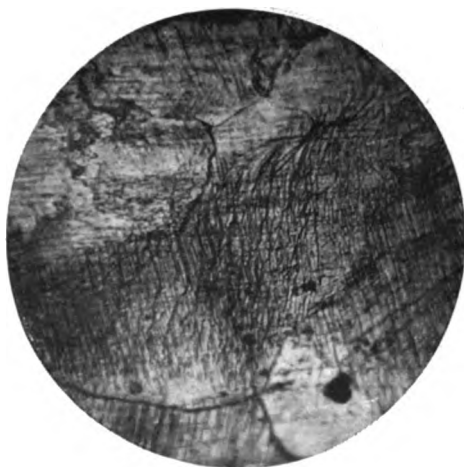


FIG. 11.

capable of useful application; it may ultimately be possible to utilise the character of the slip-bands obtained by slightly strain-



ing a specimen of a given metal to obtain such an insight into its structure as to enable us to judge of its mechanical properties.

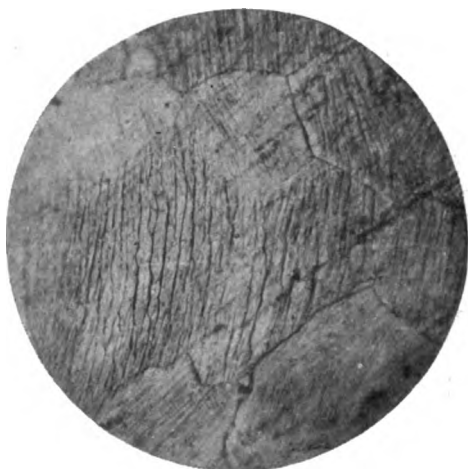


FIG. 12.

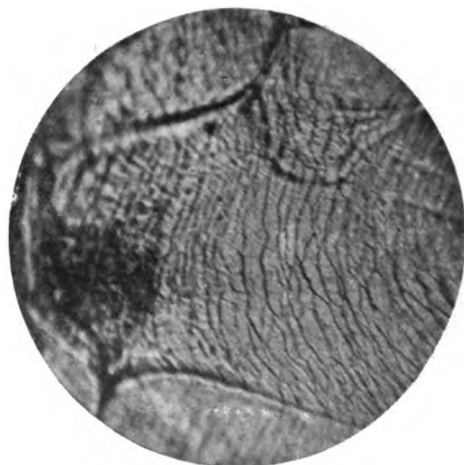


FIG. 13.

I have had an opportunity of examining some samples of steel rendered brittle by over-heating, and have found that in this

brittle metal the slip-bands developed by slight straining were distinctly different in character from those in normal metal of the same composition.\*

The next contention advanced by Messrs. Osmond, Frémont, and Cartaud against the "slip-bands" theory is that the lines are capable of crossing the inter-crystalline boundaries, and that they are frequently parallel to those boundaries. The first of these statements I am prepared to accept, with one qualification, which observation of a large number of specimens has confirmed, viz. that when a slip-band crosses an inter-crystalline boundary it always changes its direction, as a rule both in plan and elevation. When we recollect that the crystals are firmly joined at their boundaries it is not surprising to find that a slip taking place in one will be propagated into its neighbours. Osmond, Frémont, and Cartaud made the observations on which they found their statement upon a steel rendered grossly crystalline and brittle by over-heating, and it has been shown that in such metal there is a tendency for neighbouring crystal grains to have an approximately similar orientation, and under these circumstances the propagation of slip-bands from grain to grain would be more frequent, and the changes of direction less marked than in normal metal. With the second statement, that the slip-bands are generally parallel to the inter-crystalline boundaries, my observations do not agree. I must point out that the French authors' description of this observation is somewhat unsatisfactory. Thus, they state that, "When deformation is pushed further, other similar lines appear in different directions, but almost always parallel to one of the boundaries of the grain, *or of a neighbouring grain.*"† (The translation and italics are mine.) When it is considered how irregular the outlines of any single grain generally are, and that the outlines of the adjacent grains lie in all manner of directions, the looseness of such an observation is obvious. I have examined a large number of specimens of both normal and brittle metal since reading

\* It should perhaps be added here that so far, where I have referred to slip-bands in steel, this is intended to apply to the ferrite grains of the steel only, and not to the pearlite areas.

† "Quand la déformation est poussée plus loin, d'autres lignes semblables apparaissent sous des directions différentes, mais presque toujours parallèles à l'un des joints d'un grain ou d'un grain voisin."

Osmond, Frémont, and Cartaud's paper, and I am not prepared to admit that any such generalisation as to the relation between slip-bands and crystal boundaries is possible, but if I were to attempt a generalisation at all it would be to the effect that very frequently the slip-bands diverge from both sides of an inter-crystalline boundary much as the bones of a fish diverge from its spine. Fig. 14 illustrates the relation of slip-bands to inter-crystalline boundaries in strained iron.

Messrs. Osmond, Frémont, and Cartaud base a further objection to the "slip-band" theory on their experiments with a large single crystal of iron taken from a steel furnace. After an extremely interesting study of the various lines and figures which are revealed by etching the polished face of such a crystal, the French authors proceed to deform the crystal, first by pressing upon one of its faces with the edge of a knife, and then by driving a sharp point into the metal by blows from a hammer. Under the steady deforming action of the knife the surface of the crystal crumples up in the manner indicated by stress considerations, and foldings corresponding to the Lüders Lines arise. So far as it goes, this experiment seems to show that the crystalline elements of which such a crystal is composed can be deformed by suitable means, but when dealing with abnormally large crystals of metal great caution is required to avoid error, as witness the amazing results obtained by Humfrey\* when straining large crystals of lead. I think, therefore, that the effects of "static" deformation on an isolated crystal should be worked out much more fully than has yet been done before it is possible to base theoretical conclusions upon them. The experiments of deformation by shock, made by Osmond, Frémont, and Cartaud are, however, extremely interesting. They found that such a large crystal would not resist a shock applied along one of the cleavage planes, but that under these circumstances the crystal simply split or fissured along these planes. Unfortunately, Osmond, Frémont, and Cartaud interpret this to mean that under all circumstances deformation of ferrite crystals along cleavage planes can only take the form of actual fracture. This conclusion is by no means warranted. A single

\* "Effects of Strain on the Crystalline Structure of Lead." J. C. W. Humfrey, B.Sc. *Phil. Trans., R.S.*, 1902, Series A, vol. cc. pp. 225-240.

isolated crystal, subjected to direct splitting action while deprived of all support from neighbouring crystals, is in a very different position to a crystal of ferrite within a mass of metal, where it is free from any direct splitting action, and is moulded into a new configuration by the pressure of the surrounding grains. An analogy to the cleavage brittleness of large single crystals of iron is to be found in the case of ice, where large single crystals are exceedingly brittle, but masses of smaller crystals forming large blocks may be deformed very considerably without fracture. Carbonate of lime furnishes another example of this kind. The fact, therefore, that a single large crystal of

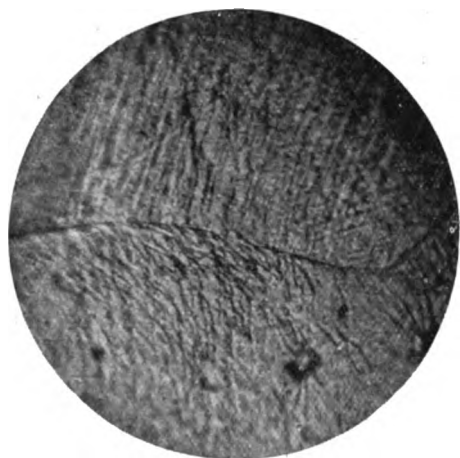


FIG. 14.

iron is incapable of slip along cleavage planes does not in the least justify the conclusion that such slip cannot occur without fracture in crystals within the mass of metal. There is, however, one phenomenon well known in connection with the plastic deformation of iron and steel which appears to me to have an interesting bearing upon the cleavage brittleness observed by Osmond, Frémont, and Cartaud; I refer to the fact that when a specimen has been strained beyond the elastic limit and is then immediately subjected to a second test, it is found to have lost its elastic properties, which are, however, restored either by the lapse of time or immediately by immersion for a

few minutes in boiling water.\* We have here, it seems to me, the analogue in an aggregate of small crystals of the cleavage brittleness of large crystals, the recovery on this view being the healing up of the surfaces of weakness left where slip has taken place.

In connection with the experiments of Osmond, Frémont, and Cartaud on an isolated crystal, and their failure to obtain lines of deformation in crystallographically oriented positions, it is interesting to recall the observations made by Ewing and Rosenhain (Paper A, Figs. 50 and 51) on certain lead-bismuth alloys, not differing very materially from the eutectic alloy in composition, but containing a few isolated crystals of one constituent. These crystals possessed definite geometric outlines, and upon straining, slip-bands were developed in them having a very sharply defined crystallographic orientation. The fact that the isolated crystal of Osmond, Frémont, and Cartaud behaved otherwise is therefore, as already suggested, probably due to the very fact of its mechanical isolation.

It further appears to me that the beautiful results of Ewing and Humfrey† on the fracture of iron under repeated reversals of stress also bear out the view here advocated. On Ewing and Humfrey's view the process of fracture under alternating stress is as follows:—

Owing to the unequal distribution of the stress between the individual crystals, and also to the different susceptibilities to slip which arise from the various orientations of the crystals, a stress which is far too low to produce yielding of the piece of metal as a whole, produces local yielding in certain of the crystals—this fact being borne out by the observation that “slip-bands” appear upon a few crystals here and there in the specimen quite early in the process. Owing to the comparative rapidity of the stress-reversals, the “healing-up” of such slips as have taken place cannot occur, and each surface of slip remains as a surface of least resistance to further slipping. As the stress is reversed, slip therefore occurs in these places, backwards and forwards over the same face, a veritable grinding

\* Muir, J., B.Sc., “The Recovery of Iron from Overstrain.” *Phil. Trans., R.S.*, 1899, vol. cxci. pp. 1–46.

† Paper C.

action being set up. The products of this grinding action actually become visible in the shape of a pile of *débris* which is seen to accumulate about each of these slip-bands. This grinding action finally results in the formation of an actual fissure, which rapidly propagates itself from grain to grain. This explanation of the previously mysterious effects of alternating stresses is, of course, entirely dependent upon the theory of "slip-bands," and to those who, like myself, have had the privilege of seeing the actual specimens of Messrs. Ewing and Humfrey it is an absolutely convincing explanation. Osmond, Frémont, and Cartaud, however, accept this explanation even less than the slip-band theory itself, although they frankly admit that they had not made any experiments of their own on this subject at the time that their paper was published. Their objections are of the same order as those already dealt with above, and I need not again enter into details. In place, however, of the clear and helpful explanation afforded by Ewing and Humfrey, Osmond, Frémont, and Cartaud content themselves with an "explanation" so vague as to be of little value. In the course of their remarks, these authors say: "When these foldings of the direct system have been repeated sufficiently often to have broken up the material, cleavages of the cube open . . ." \* This, of course, avoids the main point at issue entirely, viz., How is it that repeated foldings *do* break up the material? To this question the "slip-bands" theory as developed by Ewing and Humfrey furnishes a satisfactory answer, while none is attempted by Osmond, Frémont, and Cartaud.

There is one conclusion from the results of Ewing and Humfrey which has a possible practical bearing. The fact has already been referred to that the loss of elasticity resulting from strain beyond the elastic limit disappears either by the lapse of time or by slight warming, and I have suggested that this restoration of elasticity is due to the healing up of the surfaces upon which slip has taken place.† The effects of stress-

\* "Ces plissements du système directe multiplient et, quand ils ont suffisamment écroui la matière, des clivages du cube . . . s'ouvrent . . ."

† According to Muir in the paper already referred to, at ordinary temperatures recovery is only *complete* after five or six days, but *begins* almost immediately the load is removed.

reversals as interpreted by Ewing and Humfrey will, on this view, depend upon the fact that the reversal occurs before such healing up has had time to take place. It follows, therefore, that if the stress-reversals occurred sufficiently slowly to allow of the healing to take place between successive reversals or sets of reversals, the ultimate fracture of the piece might not result, or, at all events, would not result for a very much larger number of reversals than are required to produce fracture when the reversals are rapid. In making experiments upon fatigue effects, therefore, the rate of reversal becomes an important factor. In practice, this consideration might modify the application of factors of safety to allow for stress-reversals. From the point of view here taken, it is obvious that the conditions of a moving part of a machine suffering stress-reversals several hundred times per minute, approximate to those of the usual fatigue experiments, but that the time effect may play an important part when the effect of stress-reversals on structures which are only subjected to their load at comparatively long intervals of time is considered.

Returning to the slip-bands theory itself, it must be borne in mind that one of the strongest arguments for the crystalline character of these lines is their obvious and close connection with so purely crystallographic a phenomenon as that of twin crystals. In the case of lead, copper, and other metals, this connection has been fully demonstrated by Ewing and Rosenhain (Paper A, Figs. 34—41, inclusive). So far as I am aware, however, twin crystals as revealed by slip-bands have not hitherto been described in iron or steel. This gap in the evidence I am now able to fill up, having observed unmistakable twin systems of slip-bands in some specimens of transformer iron strained not very far beyond the elastic limit in simple tension. One of these is illustrated in Fig. 15. The photomicrograph shows very clearly the characteristic change of direction and subsequent return to the original direction of slip-bands associated with twin crystals, and I have observed a number of similar examples. In fact, it now appears probable to me that twinning is in reality a frequent phenomenon in iron. Such large "steps" in slip-bands as that illustrated in Fig. 8 are probably associated with twin formations. Twin crystals in iron have,

it should be stated, been demonstrated by Osmond, and the novel point here brought forward is the fact that slip-bands follow, or rather reveal, the existence of twin formations. This fact is a strong argument in favour of the truly crystalline nature of the lines as indicated by the "slip-bands" theory.

Messrs. Osmond, Cartaud, and Frémont base further objections to the "slip-band" theory on their observations of certain lines of deformation exhibited by non-crystalline bodies, such as gelatine, glue, and putty. I have carefully repeated several of the experiments upon these substances which they describe, and have observed the lines of deformation that arise. For instance,



FIG. 15.

when a sheet of gelatine is broken by bending, the surface near the fracture is covered with microscopic lines. I have not been able, so far, to determine the exact character of these markings, but examination under oblique light, as described at the beginning of this paper, at once distinguishes them from slip-bands. The same remark applies to the markings obtained by deforming a non-crystalline granular body, such as the aggregate of lumps of putty described by Osmond, Frémont, and Cartaud; in this case the markings are due to rounded folds on the surface, which may be obtained large enough to observe as such. The comparative roughness of the surface of such bodies interferes



with the use of oblique light. That an amorphous body will crumple up, especially under compressive deformation, is of course a well-known and readily understood fact, but the similarity between these deformations and the definite lines and steps observable in crystalline metal is far too vague to furnish an argument against the "slip-bands" theory.

In a most interesting portion of their paper, Osmond, Frémont, and Cartaud deal with the appearances to be observed upon repolishing and etching a specimen of strained iron. By the use of picric acid as an etching agent, they have been able to observe and identify certain markings, hitherto unknown, which are to be found upon strained metal—a result to which their ingenious methods and skilled observation have largely contributed. Osmond, Frémont, and Cartaud, however, appear to be surprised to find that upon repolishing and etching a surface upon which slip-bands had been developed no traces of the former slip-bands are revealed. This fact leads the French authors to speak of these lines as "superficial deformations." On the slip-bands theory, however, the deformations are not superficial; the lines observed are necessarily upon the surface, but they are the trace or representative of what has been going on throughout the mass of the metal. As this deformation consists of a sliding movement of the crystalline elements within each grain, without any disturbance of their shape or orientation, except in the case of twinning, we should not expect to find any trace of such disturbances on repolishing and etching the surface of the strained metal. As it has been shown, both by Heyn, and more completely by the French authors, that subsequent etching reveals certain changes in pattern which result from previous straining, it is necessary to point out a consideration bearing on this matter. I have already referred to the fact that freshly strained iron differs in mechanical properties from strained iron which has been allowed to "recover" either by the lapse of time or by slight warming, and the connection between this phenomenon and "slips" has been suggested. If, therefore, it were possible to repolish and etch a specimen *immediately* after the application of the strain, and to do this without any heating of the surface, it appears probable that traces of the slip-bands would be found.

The mere act of rubbing the specimen on emery paper or rouge pad, however, heats its surface quite sufficiently to cause recovery to set in. On the slip-bands theory this involves the healing up of the surfaces of slip, and the consequent absence of their traces on re-etching the surface. Some caution is, in fact, always necessary in interpreting the results obtained by etching metallic surfaces prepared by polishing, when it is desired to draw conclusions as to the physical state of the material. The process of preparing the surface, generally by a succession of mechanical abrasions, must materially alter the physical condition of a layer of metal on the surface,\* and only when this layer has been removed by etching can the true condition of the metal be judged. This altered surface layer will be comparatively deep in so soft a material as ferrite. Further, it is difficult to form any idea of the thickness of this surface layer, and especially to ascertain that it has at any stage been removed from the whole of a given etched area. If, for example, the specimen has been filed down preparatory to polishing, it is very probable that in a number of places the finished surface will not lie far below the original level of the bottom of the deepest groove made by the file, while in other places the local mechanical disturbances will only be due to the light cut of the finer emery papers. The method of Heyn, who etches his preparations deeply with copper-ammonium chloride, is less open to objections on this score than that of Osmond, Frémont, and Cartaud, who etch very lightly with picric acid. The observation of confused and unintelligible etching patterns on single ferrite grains when lightly etched with picric acid, and the possibility of occasionally tracing the local effects of deep grooves which existed prior to the later stages of the preparation, has led me to put forward these considerations. For the immediate purpose of the present argument it has, I think, been made clear that the fact that slip-bands cannot be traced on a repolished and re-etched surface of strained metal is no evidence of the "superficial" character of the deformations they represent. In certain cases, MM. Osmond, Frémont, and Cartaud find "fringes" in strained and etched iron, obviously remnants of the deformation which

\* Beilby, George, "The Surface Structure of Solids," *Journal, Soc. Chem. Industry* vol. xxii. No. 21, 1903.

has taken place, but the explanation of this phenomenon is difficult, and has not been attempted by the French authors.

Much more clearly defined are two other features observed by the same authors on etching strained metal; these they name "Joint Bordées" "Épines" (Bordered Boundaries and "Spikes," respectively), and I propose to adhere to the nomenclature of the distinguished discoverers. The former feature, consisting of markings which in a general way follow the inter-crystalline boundaries and "border" them as with a decorative fringe, is of special interest to myself, as it furnishes evidence, from the point of view of the effects of deformation, of a theory of the structure of inter-crystalline boundaries for which I have been able to obtain evidence in several other directions. I now propose to outline this theory, and the explanation of Osmond's bordered boundaries which it affords will follow in the natural course of the argument.

The question which, to my mind, requires an answer is: What is the mechanism of the very powerful cohesion between adjacent crystalline grains in a pure metal? \* It has been observed by several metallographers that, in a metal free from injurious impurities, fracture does not, as a rule, follow the inter-crystalline boundaries, but runs across the crystalline grains themselves. The fracture of many other crystalline aggregates follows the same law, as may be readily seen on examining the fracture of a piece of crystalline granite. This fact implies that the cohesion across the junction between adjacent crystals is greater than that within the body of either, and at first sight this is a little difficult to understand.

The explanation is, I believe, to be found by considering the manner of growth of crystals and crystalline aggregates when they are first formed, *i.e.* in the simplest case, in the solidification of a pure metal from a state of fusion. This process has

\* At the outset of this section of my paper I wish to acknowledge the extremely valuable work already done by Professor Arnold upon the question of inter-crystalline boundaries. So near, indeed, has Professor Arnold come to the ideas to be developed here, that he has actually used the term "interlocking" in connection with crystal boundaries. The theory of interlocking based upon intermediate dendritic forms of crystallisation here outlined is, I think, a further step in the explanation or attempted explanation of these complex phenomena.

already been described by Ewing and Rosenhain (Paper B, p. 290), and more fully still by Heycock and Neville.\*

In most cases where the act of solidification has been studied, it has been found to take place by the formation of a number of skeleton crystals. A number of branches shoot out from each centre of crystallisation, and the body of the crystal is subsequently filled in by other arms branching from the first set, a third set branching from the second, and so on. In many cases the process of solidification is stopped before the skeleton crystals are filled in, as, for example, when certain copper-tin alloys are chilled from a high temperature. The micro-sections of some of these alloys show well-developed dendritic forms which represent the unfinished crystals.† Similar forms can be obtained by melting lead in a flat dish and pouring away the fluid remnant when about half the metal has again been allowed to solidify. That the same process of crystallisation by the formation of skeleton arms can occur in the case of iron under certain conditions is proved by the appearance of the well-known "fir tree" crystals of iron sometimes found in drusic cavities of ingots. The extent to which these skeletal arms are developed will depend very much upon the conditions of crystallisation. Under some conditions the process of filling up the interstices between the first system of branches follows so rapidly upon their first formation that it is impossible to stop the process at a stage which would still enable us to see the actual branches. Judging by analogy from the crystallisation of salt solutions, we should expect to find that very gradual crystallisation would occur without any visible formation of skeletal arms, and—at the other extreme—very rapid crystallisation would have the same effect, while at certain intermediate rates of crystallisation the dendritic forms would be well developed. To this point it will be necessary to recur later.

For the immediate argument it is sufficient to show that, under certain conditions, iron may develop dendritic forms of crystallisation. On the other hand, although ordinary cast lead shows no signs of dendritic structure, it has been observed to

\* Heycock and Neville, "On the Constitution of the Copper-Tin Series of Alloys," *Phil. Trans., R.S.*, 1903 (Bakerian Lecture), Series A, vol. ccii. pp. 1-69.

† Heycock and Neville, paper referred to above (Figs. 1, 10, 42).

pass through that stage in a conspicuous degree, both in its primary crystallisation and in re-crystallising in the solid after strain (Paper B, Figs. 26 and 27, and pp. 287-290).

The importance of the dendritic stage of crystallisation becomes apparent on considering the manner in which growing crystals will meet. The skeleton arms start from a number of independent centres, each following the geometric law governing the crystal to which it belongs. These random arms will not, as a rule, meet exactly end to end; the growing end of one



FIG. 16.

arm will frequently meet the side of an arm coming from another centre. Under these circumstances a certain amount of interpenetration and interlocking of the secondary branches will result. To a certain extent this process will be limited, in the case of a solution or alloy, by the local exhaustion of the crystallising material, and even in the case of a pure metal there will be a tendency to avoid actual contact between the crystal arms until nearly the whole metal is solidified. On the other hand, Heycock and Neville have found that when only one con-

stituent of certain copper-tin alloys has crystallised, these skeleton crystals surrounded by their mother liquor form a body stiff enough to resist considerable tension—a resistance which can be readily accounted for by the interlocking or “gearing up” of these skeleton systems at their meeting-points. Illustrations of this interlocking of skeleton crystals can be found in the case of salt solutions allowed to crystallise under conditions favouring the development of dendritic form. Fig. 18 is a photomicrograph of dendritic crystals of ammonium-chloride, formed in a thin solution of gelatine spread upon glass.

On these considerations I base the view that inter-crystalline cohesion arises from the interpenetration or the interlocking of skeleton arms formed by the growing crystals. To find confirmation of this view, certain conclusions which arise from it may be followed out. The first and most obvious of these is that in a pure metal the boundary between one crystal and its neighbour is not a definite sharp surface, which in section would appear as a single line, but that there is a certain space about the boundary in which the material belongs partly to one crystal and partly to the other, producing in section a narrow area of mixed orientation. This area would be bounded upon either side by a line drawn through all the extreme points belonging to the branches of one crystal. The question arises, How would such an area of mixed orientation behave on etching and straining? As regards etching, I think it is clear that the rate at which such an area would be acted upon by a solvent would differ from that at which either of the adjacent crystals would be acted upon; probably the area of mixed orientation would be dissolved more rapidly than the surface of either of the adjacent crystals. The result will be the formation of a channel, with steep and somewhat ragged sides of different depths, since the level of the two crystals is different in the etched specimen, and with a more or less flat bottom. The effect is shown in diagram, Fig. 17. AB is the etched level of one crystal, BC the steep slope down to the bottom of the channel, CD the more or less flat bottom of the channel, DE the steep slope up to the face, EF, of the other crystal. This diagram supposes that the boundary between the two crystals runs downward almost normally into the mass of the section.

If this boundary runs at a considerable angle, one slope of the etched channel will overhang more or less, possibly overhanging the entire channel of the opposite slope. Seen under vertical light, as indicated by the arrows on the diagrams, the section illustrated in Fig. 17 would show two nearly parallel black lines, more or less serrated, with a light band between them.

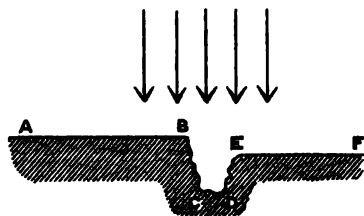


FIG. 17.

In the other case, illustrated in Fig. 18, only one black line would be seen, viz., the shadow of the overhanging edge of the higher crystal, and this would disappear or increase in width as the incidence of the light was slightly altered from the true vertical in one or the other sense. Micrographic appearances corresponding to these two cases are numerous in pure iron and soft steel; in the first case, the appearance is that of apparently double inter-crystalline boundaries, and in the second case of

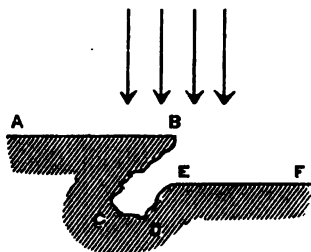


FIG. 18.

boundaries whose appearance changes considerably as the specimen is moved across the field, or as the incidence of the "vertical" light is slightly altered in other ways. A good example of these double boundaries is shown in Fig. 2 of Paper A. The specimen there photographed was etched with dilute (0.1 per cent.) nitric acid, but more recently I have used

other etching reagents such as tincture of iodine and picric acid. In every case I find that on etching a pure iron, such as good Swedish, or very soft steel, like that used for magnetic purposes, double boundaries appear when the etching has been carried to a certain depth. In some cases very high magnification ( $\times 1500$ ) is required to reveal them. It would perhaps be going too far to say that all the boundaries appear double, but in some specimens a single boundary is an exception. Fig. 19 shows double boundaries between ferrite grains seen under high

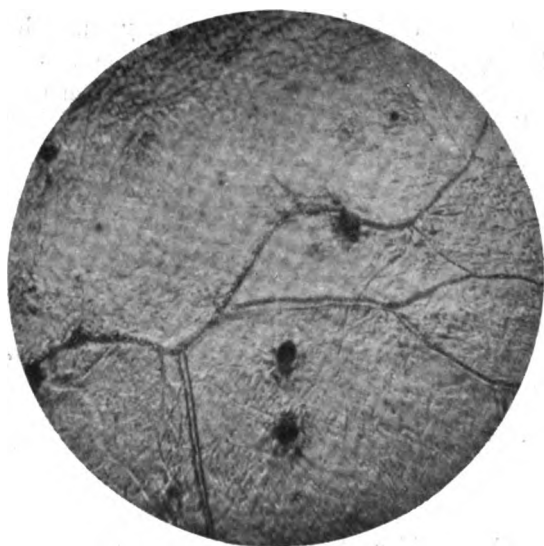


FIG. 19.

magnification. It might perhaps be suggested that these double boundaries are due to a layer of another constituent interposed between the crystalline grains, but a close examination of the specimens disposes of this possibility. The area between the double boundaries possesses none of the properties of cementite, since it is not left in relief by polishing on a soft pad, and as neither iodine nor picric acid produce any stain, the presence of pearlite and of most impurities is precluded. In the very pure iron here dealt with, in fact, the proportion of the total area occupied by these double boundaries is too large to be



accounted for on the hypothesis of a chemically different constituent. Such an hypothesis is further discounted by the fact that minute patches of cementite and pearlite could be distinguished upon the specimens at places quite distinct from those here referred to.

If the etching be carried a little too far, it becomes difficult to recognise the double boundaries, as the channel is then deepened and often lost to sight in the shadow of the sides, thus giving the effect of deep grooves. The occurrence of such deep grooves on etching chemically pure metals has often been observed and has led to some difficulty and controversy, but I believe that the ideas here put forward may afford a satisfactory explanation.

The behaviour of these double boundaries under strain cannot easily be followed directly. The maze of lines formed by straining makes it difficult to trace the original outline of the double boundaries; but indirect effects of the interlocking between adjacent crystals are traceable. On the slip-bands theory, these interlocked boundaries, owing to their mixed orientation, must present great resistance to slip, forming a species of physical network or cells, such as Osmond's theory of cellular structure demands. Owing to the intimate connection between one crystal and its neighbours, we should expect to find that movements in one are transmitted to others. In fact, it would seem that the first yielding to applied stress must take place in these regions of mixed orientation, and any movement occurring there would carry with it the less resisting masses of the crystalline grains themselves. That this is actually the case is borne out by the relation of the slip-bands to the boundaries. In the great majority of cases the slip-bands are seen to rest with one end upon a boundary—a "loose" slip-band, having neither end upon a boundary, is at all events rare. That the first slip-bands start from inter-crystalline boundaries is strikingly shown in most of the photographs published with the paper of Ewing and Humfrey (Paper C). Figs. 11 and 12 of that paper show the effect particularly well, while Fig. 14 of the present paper illustrates the same feature. Another consequence follows from the relative rigidity of the regions of mixed orientation at the inter-crystalline junctions. Not only will yielding commence in these regions, but, with a given amount of deformation the edges of these

regions will be the most distorted—they will not behave continuously with the adjacent portions of the crystals proper, and consequently much disturbance of structure will be found in their neighbourhood after severe strain. This disturbance will probably take the form of complicated arrangements of twin lamellæ. It is these special disturbances of structure which subsequent etching will most readily reveal, in the form of the "spikes" and "bordered boundaries" of Osmond.

Having shown that a number of well-defined phenomena are readily explained by the view that a certain amount of interpenetration takes place in the formation of the crystalline grains of a metal, some further considerations remain to be dealt with.

In the first place it is evident that in a pure metal, or in any metal where the strength of the material is dependent upon the inter-crystalline cohesion between adjacent crystals of the same constituent, as is the case in the softer steels, the strength and reliability of the metal will be greater the larger the total proportion of the bulk which is occupied by these regions of mixed orientation. Provided that the amount of interpenetration be the same, this proportion will increase as the number of boundaries increases, *i.e.*, as the size of the crystalline grains diminishes. It must, however, be remembered that the crystals to be reckoned with in the case of ferrite are formed in a solid and—if the metal be forged at those temperatures—they are formed under extreme mechanical disturbance of their mother-solid. It is, then, a matter for further investigation to discover that method of heat and mechanical treatment which, while keeping the size of the crystalline grains themselves as small as possible, will result in the greatest possible amount of mutual interpenetration. It will very probably be found that methods which are known to give good mechanical results fulfil these conditions, although it may perhaps be hoped that even better results may follow from the application of the present theory. It is, however, of interest to refer here to the well-known fact, investigated by Arnold\* and Longmuir† that the temperature

\* Arnold, J. O., "Properties of Steel Castings," *Journal of the Iron and Steel Institute*, 1901, No. I. p. 175.

Arnold and Jefferson, "Influence of Small Quantities of Impurities on Gold and Copper," *Engineering*, Feb. 7, 1896.

† Longmuir, P., "On the Influence of varying Casting Temperatures on the Properties of Alloys," *Journal of the Iron and Steel Institute*, 1903, No. I. p. 457.

of casting has a vital influence upon the mechanical properties of metals. In the case of complex alloys other factors are doubtless at work, but so far as I am aware the cause of these effects of casting temperature has not hitherto been fully understood, although Arnold refers to the fact that when cast at the proper heat inter-crystalline junctions in very mild steel are not so clearly defined. According to the view here taken the effect of too high or too low a casting temperature would be to reduce the tendency to the formation of intermediate dendritic forms of crystallisation, while the proper casting temperature would secure such a rate of cooling or crystallisation as to produce the greatest amount of dendritic formation and consequent interlocking.

It is, however, important to notice that the amount of interlocking between the skeletal arms of adjacent crystals is not solely a function of the rate of cooling or of any temperature condition, but that it is also a question of mechanical treatment. If we suppose that at any moment the mass of the crystallising metal is full of these intermediate dendritic forms, and that at such a moment it were possible to compress the mass, not as in the Whitworth process by simple hydrostatic pressure, but in such a manner as would tend to squeeze out the still liquid portion, the result would be a crushing together of the dendritic skeletons, and a consequent increase of the amount of interpenetration. In the case of steel castings these conditions are obviously not at all easy to realise in practice even on an experimental scale; when the metal, however, is forged, the mechanical pressure exerted at a time when re-crystallisation is taking place may cause increased interpenetration, and it is possible that such an action may lie at the root of the well-known improvement of mechanical properties which results from forging under proper conditions. In order to obtain some confirmatory evidence for my views on inter-crystalline cohesion and the effect of suitable pressure upon a crystallising metal, I have had recourse to experiments upon lead, whose convenient melting point and well-marked crystallisation render it suitable for such a purpose. An iron mould was prepared, one side of which consisted of a movable plunger which could be forced inward when desired. As the top of the mould remained open, forcing the plunger

inward caused the level of the metal to rise in the mould, leaving behind the solid portion partially attached to the side, and thereby to a certain extent straining off the remaining liquid. In this mould an ingot of lead was first cast, allowed to solidify at rest, and removed. Then a second ingot was cast, and the plunger driven inwards during the gradual solidification of the metal. Both ingots of lead were then planed flat and etched by electrolytic means until the surface layer of small disturbed crystals which resulted from the planing was entirely removed. The scale of the structure of both specimens was approximately the same, but while the specimen which had been allowed to crystallise at rest showed the usual sharply defined boundaries, the specimen which had been subjected to pressure while crystallising, showed greatly serrated and indented boundaries, and in some places the boundaries were very indistinct. Figs. 20 and 21 show the characteristic boundaries of the crystalline grains in the two specimens of lead thus treated, both to the same scale of magnification.

In the preceding portions of this paper the nature of the argument has rendered it necessary to describe observations and inferences without reference to their novelty. I therefore append a summary of those observations described and inferences suggested in the present paper which I believe to be novel.

#### SUMMARY.

The first point which has been dealt with in connection with new observations is the explanation of the "curved" slip-bands in iron and mild steel. The conception that the curvature of slip-bands might be accounted for by minute stepping of the lines is already mentioned in Paper A. In the present paper, however, new micrographic evidence in favour of this hypothesis is advanced (Figs. 6, 7, 8) and a fresh line of evidence is brought forward by the examination of slip-bands in iron under the highest power available with oblique light. Such examination is shown to resolve the slip-bands which appear as continuous but curved lines under vertical light, into discontinuous lines whose curvature is much less apparent (Fig. 9). The dark



FIG. 20.



FIG. 21.

gaps in the slip-bands as seen under such illumination are ascribed to minute steps along gliding surfaces having a different orientation. The "curvature" of slip-bands in iron having been shown to be probably due to a multitude of minute steps, a reason is suggested why this stepping should be so marked a feature in iron, while it is so comparatively rare in certain other metals. This reason is that the ferrite crystals in ordinary iron and steel are formed by crystallisation from a solid, while the ordinary crystals of lead, for instance, are formed by crystallisation from a true liquid. By producing lead crystals in strained and annealed lead, and showing that the slip-bands in these crystals also commonly assume stepped or "curved" forms, the probable truth of the suggested explanation is demonstrated (see Figs. 10, 11, 12, and 13).

The truly crystalline character of slip-bands is further demonstrated in a novel manner by the observation of slip-bands in iron following and revealing the gliding planes of twin crystals. (Fig. 15.)

Finally, the view has been advanced that the strength of inter-crystalline cohesion in pure metals and certain forms of alloys is due to the interlocking of the skeleton arms which the crystals develop during their first formation. According to this view, the inter-crystalline boundaries take the form of regions of mixed orientation, and certain consequences are to be deduced from this consideration. It is argued that, since a region of mixed orientation must offer greater resistance to slip than a region of uniform orientation, the inter-crystalline boundaries form a network of cells upon which the true resistance of the metal depends. Plastic deformation sets in when these cell-walls begin to give way; in doing so they will carry with them the less resisting masses of the crystalline grains. In this way the observed relation between slip-bands and inter-crystalline boundaries, which is illustrated in Fig. 14, is explained. Observations of a frequent doubling of the inter-crystalline boundaries between ferrite grains in pure iron (Fig. 17) and the "bordered boundaries" and "spikes," discovered by Osmond, Frémont, and Cartaud, in strained metal are adduced as further evidence in support of this view of the structure of inter-crystalline boundaries.

The bearing of this theory on the influence which casting temperature exerts on the structure and strength of castings is discussed, and the effect of mechanically disturbing the crystallisation of a metal is considered—first, in reference to the effect of forging iron and steel, and, finally, an experiment is described showing the effect of mechanical disturbance during the act of crystallisation upon the inter-crystalline boundaries of ordinary lead. (Figs. 18, 19.)

In conclusion, I wish to express my thanks to the following gentlemen for the kind help they have afforded me, especially in furnishing me with the specimens of metal which I have used in the present investigation: Mr. Alex. E. Tucker (to whom I owe special thanks in connection with the appended analyses of the materials employed), Mr. A. H. Hiorns, Mr. A. H. Peake, and Mr. W. H. Merrett. For the preparations of the specimens and other help I am indebted to the skill and patience of Mrs. W. Rosenhain.

To avoid interrupting the thread of the argument throughout the paper, I have omitted all details of the photomicrographs; I now append these in the following:—

#### LIST OF PHOTOMICROGRAPHS.

Figs. 3 and 4. Two views of the same field of transformer iron, etched with picric acid and strained in direct tension to show slip-bands. Oblique light,  $\times 160$  diameters. Material A.

Fig. 5. Swedish iron, reduced to half its original thickness by hammering in the cold.  $\times 80$ , oblique light, showing the "oriented lustre" of a crystalline metal. Material B.

Figs. 6 and 7. Slip-bands in strained Swedish iron, showing the stepped character of slip-bands. Vertical light,  $\times 1450$  Material B.

Fig. 8. Ditto.  $\times 440$ . Material B.

Fig. 9. Slip-bands in strained transformer iron, oblique light,  $\times 240$ , illustrating the discontinuous appearance of slip-bands under such illumination. Material A.

Fig. 10. Slip-bands in cast lead, vertical light,  $\times 160$ , illustrating straight slip-bands.

Figs. 11 and 12. Slip-bands in annealed lead, vertical light,  $\times 160$ , illustrating curved or stepped slip-bands in lead.

Fig. 13. Slip-bands in Swedish iron, vertical light,  $\times 1450$ , for comparison with Figs. 11 and 12. Material B.

Fig. 14. Inter-crystalline boundary with slip-bands in strained Swedish iron, etched with picric acid and strained by bending. Illustrates the relation of slip-bands to boundaries. Vertical light,  $\times 1450$ . Material B.

Fig. 15. Slip-bands in transformer iron, showing twin crystals. Vertical light,  $\times 300$ . Material A.

Fig. 16. Skeleton crystals of ammonium chloride in gelatine, transmitted light,  $\times 14$ , illustrating interlocking of skeleton crystals.

Fig. 19. Double boundaries between ferrite grains in Swedish iron. Vertical light,  $\times 1450$ . Material B.

Figs. 20 and 21. Cast lead, oblique light,  $\times 40$ , showing smooth and serrated inter-crystalline boundaries resulting from undisturbed and disturbed crystallisation respectively.

Analyses of materials by Mr. Alexander E. Tucker, of Birmingham :—

	Material A. Per Cent.	Material B. Per Cent.
Carbon . . . . .	0.102	0.117
Manganese . . . . .	0.525	trace
Silicon . . . . .	0.042	0.021
Phosphorus . . . . .	0.052	0.018
Sulphur . . . . .	0.036	0.007



## CORRESPONDENCE.

Professor J. A. EWING (Greenwich) congratulated the author on a particularly interesting and suggestive paper. The first part of it consisted of a lucid and careful *résumé* of the evidence which had led the author and himself, five years ago, to their discovery of "slip-lines," and to the interpretation which they had put on the phenomena they then observed. To restate the case was no doubt desirable, in view of the critical attitude assumed by M. Osmond and his colleagues. Their criticisms certainly seemed to be based on an imperfect appreciation of what that evidence was: in particular, they made no reference to the evidence furnished by oblique illumination, and that in itself was absolutely conclusive. It was surprising that so acute and experienced an observer as M. Osmond should be under a misapprehension on points which did not really admit of any doubt. If he rightly understood the position of MM. Osmond, Frémont, and Cartaud, they accepted slip-lines in other metals, such as cast-copper or lead, but rejected them in iron, because in iron they were not straight. But the identity in character of the lines in iron and other metals was obvious, when one examined them under oblique light, and, as Mr. Rosenhain had well pointed out in this paper, it was easy to get the same curved lines in lead or in iron by using a specimen in which crystallisation had taken place, as it does in iron, when the metal was already in the solid state.

Why this difference should occur as between crystals formed from the liquid and from the solid was an interesting point to which Mr. Rosenhain's views regarding interlocking suggested a partial answer. There would probably be more tendency to interlock at the boundaries in crystallising from the solid. But another reason might also be expected to be operative. The crystalline grain formed in solidifying from a liquid was more homogeneous than the grain formed by recrystallisation in its solid state. Foreign constituents had more freedom to escape in the former; and those that did not enter by solid solution into the main substance of the grain would, for the most part, be segregated at the boundaries, mainly in the state of eutectic

layers cementing the grain to its neighbours, thus leaving the bulk of the grain in a nearly homogeneous state. In recrystallisation from the solid it was much more likely that foreign matter would fail to escape. Particles would be imprisoned during the dendritic growth of the new crystal, thereby producing a grain with less homogeneity, in which the slips caused by straining would be less likely to follow individual cleavage planes across the crystal, and more liable to jump by steps from one cleavage plane to another as a consequence of the local difference in resistance to slip from point to point within the substance of the grain. To this might be ascribed the stepped character of the slip-lines in iron or in lead recrystallised from the solid state, and, as Mr. Rosenhain had explained, it was in consequence of such steps that the slip-lines appeared to be curved.

By way of supplementing the experiments cited by Mr. Rosenhain, as demonstrating the relation of the slip-lines to the crystalline structure of the grain in metals generally, he might refer to the paper by Humfrey.\* The structure of the grains was there developed on an exceptionally gross scale, and the geometrical relation of the slips to the crystalline axes was made exceedingly apparent (see Figs. 7 and 8 of Humfrey's paper).

With regard to the author's suggestive remarks on interlocking between contiguous grains, it should be borne in mind that the region in which any interlocking takes place is also the region in which small quantities of any eutectics that may be formed as a result of the presence of impurities will be collected. Assuming interlocking to occur, the lattice-work of interlocked ends will have its interstices filled by such constituents. These may contribute to make the border region less easy to deform than the substance of the grain, and in the etching process they will do much to make it more readily attacked.

Mr. J. E. FLETCHER (Sheffield) wrote that Mr. Rosenhain's paper formed a most helpful addition to the investigations previously conducted by that gentleman in conjunction with Professor Ewing, and his closely reasoned conclusions had a

\* *Phil. Trans.*, vol. 200, 1902, p. 225.

special bearing upon the question of the so-called "fluid compression" of steel. The compression of steel during solidification had a metallurgical effect in addition to the purely mechanical one of reducing the gas cavities, and it was to this point (which appeared hitherto to have been overlooked) that attention should be drawn, especially in view of an opinion expressed in another paper that the only value of compression was to "mask some of the defects of steel that had been badly melted." A careful study of the crystalline changes occurring in steel whilst being worked (hammered, pressed, or rolled) at various temperatures would appear to indicate that a sliding action takes place not only between separate crystals, but also within the individual crystals themselves, when low carbon steels are worked at temperatures below  $700^{\circ}\text{C}$ . Such sliding action was in some cases clearly visible under low powers of magnification, especially in alloy steels containing nickel, the structures of which had been well defined by Mr. Osmond as "schistose"; and this sliding action showed itself to be greatest in the direction of *greatest flow* during the working of the steel, and least in the directions at right angles thereto. It would therefore appear to be a reasonable suggestion, judging from the results of transverse tests from plates and forgings, that such crystalline deformation was the cause of the differences found in the tensile strength and elongation of test-pieces taken respectively transversely and longitudinally to the direction of greatest flow during the plastic working of a bar, plate, or forging. When a steel ingot was worked into a bar, plate, or shaft of several times its length, surely each crystal must be proportionately lengthened in the operation, whilst its cross sectional area at right angles to the direction of lengthening is diminished. But as the outside of an ingot cools more rapidly than the inside, the size of the crystals must be smaller where the cooling has been more rapid, so that the finished forging or rolled bar would be of finer crystalline structure in the outside portions than is the case at the centre of its mass, and during working under the hammer press or rolls the magnitude of the sliding action must be different amongst the *internal* crystals from that which occurs amongst the *external* ones. The ideal importance of securing uniform size of the crystals in

the ingot in the first instance would therefore appear to be obvious, though this is of course unattainable in the case of ingots whose exterior was slowly cooled without "compression." In the case, on the other hand, of the Harmet process, of subjecting the gradually cooling mass of steel in an ingot to a gradually increasing pressure until complete freezing had taken place, the conditions laid down by Mr. Rosenhain were more or less attained, since in this case the method of compression adopted tended continually to squeeze out the internal fluid portion, whilst the outer envelope of the ingot was solidifying under pressure, and therefore a much greater degree of uniformity of crystalline structure was produced throughout the ingot, since the wire-drawing effect of the Harmet system caused the dendritic crystals to be pressed together, and thus prevented from acquiring the large cellular structure found in the case of slowly cooled steel, whilst the enforced continuous contact of the ingot surface with that of the thick mould used in the process enabled much more rapid cooling than was possible with a non-compressed ingot. It had also been noticed during the working of the process that the violence of the recalescence was reduced in intensity, the maximum pressure being brought to bear on the cooling mass whilst it was passing through the whole recalescence range.

It might be added that the results obtained in the subsequent working of large numbers of ingots compressed on the Harmet system at the works with which he (Mr. Fletcher) was connected, had shown conclusively how great was the value of the Harmet system in insuring a consolidated centre possessing inter-crystalline cohesion, instead of the more or less spongy structure of a slowly cooled mass of metal, the outer envelope of which, solidifying first, had hindered the free contraction of the interior portions. The mechanical tests for a given analysis had uniformly given better results, especially in the case of cross tests taken from the central portion of the compressed steel, than could be obtained from the central portions of similar forgings manufactured from non-compressed ingots under the most favourable conditions.

Professor E. HEYN (Berlin) considered that in the present paper Mr. Rosenhain appeared to carry the generalisation as to the effects of slip still further than formerly. If Professor

Heyn rightly understood the paper, Mr. Rosenhain's view is that plastic deformation without slip-bands is impossible. This view he was not prepared to accept.

The slip-bands are identical with the "Translationsstreifen" which had been previously observed by Mügge, and the same investigator had established the fact that only a part of the deformation of crystals takes place by slip, another part being due to the formation of twins, as in the classical example of calcite.

On page 341, footnote, it was said that he (Professor Heyn) had in his possession a photograph of a specimen "in which a change of orientation of the etched figures within one crystalline grain was observed after severe deformation," and Mr. Rosenhain says further: "This is, however, no proof that the crystalline elements themselves have been deformed, as it would appear unlikely that if deformation took place at all, it would merely alter a rectangular figure into an oblique parallelogram." Professor Heyn had never maintained that the crystalline elements themselves are deformed, but took the view that in the case cited a fan-like alteration of shape of the crystal had taken place, and Mügge quotes a whole series of similar cases.

Mr. Rosenhain says that "I regard it as likely that careful search will reveal slight variations of orientation within the crystalline grains of unstrained iron and steel." Such careful investigations of the etching figures of undeformed iron have been carried out by Professor Heyn in large numbers, and lead him to conclude that Rosenhain's supposition is not well founded.

The remarkable feature of the so-called slip-band in soft steel is the following: that while in the case of copper the "slip-bands" appear as soon as the slightest deformation has taken place, in the case of ordinary varieties of steel low in carbon it is necessary to proceed to a very considerable deformation before the curved lines—"slip-bands"—appear. Professor Heyn has observed instances where flow-lines had already appeared upon rods under tension, and the individual ferrite grains had already begun to protrude from the surface, rendering it rough, and yet the slip-bands only appeared after considerable further deformation, and were then crooked. Professor Heyn could only account for this by supposing that some other kind of plastic

deformation had preceded the appearance of the slip-bands; when these appear upon crystals which have already been considerably deformed, they will naturally be curved. In iron which has been strongly overheated, slip-bands were observed to appear with much smaller deformations, and were then entirely rectilinear, as in copper; they were then undoubtedly slip-bands.

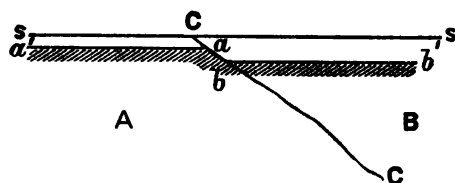
On page 350 Mr. Rosenhain says:—"I think, therefore, that the effects of static deformation on an isolated crystal should be worked out much more fully than has yet been done before it is possible to base theoretical conclusions upon them." Such experiments have been made on an extensive scale by Mügge. It is, however, not enough that such experiments should be made, the published accounts should also be read.

Page 354: "In fact it now appears probable to me that twinning is in reality a very frequent phenomenon in iron." This statement is illustrated by Fig. 15, and Mr. Rosenhain has observed similar appearances in samples of transformer sheet which had not been strained very far beyond the elastic limit. Professor Heyn does not understand how one can immediately conclude from these observations that it is "a very frequent phenomenon." Professor Heyn had not so far observed a single instance of twin-structure in undeformed iron; in deformed material he believed that he had observed a single instance, and he had ascribed the origin of this twin structure to the deformation; might not this be the case also with the examples cited by Mr. Rosenhain?

Pages 356 and 357: "If it were possible to re-polish and etch a specimen immediately after the application of the strain, and to do this without any heating of the surface, it appears probable that traces of the slip-bands would be found. The mere act of rubbing the specimen on emery-paper or rouge-pad heats its surface quite sufficiently to cause recovery to set in. On the slip-bands theory this involves the healing up of the surfaces of slip, and the consequent absence of their traces on re-etching the surface." This is contradicted by the following experiment which Professor Heyn has repeatedly performed upon copper. A finished section of copper was deformed so as to show slip-bands. Thereupon the specimen was immediately

lightly etched with nitric acid or ammoniacal copper-ammonium chloride. The lines immediately disappeared. What becomes of the healing-up theory? Mügge has long ago explained the phenomenon, and the writer has incorporated his explanation in his paper, *Die Umwandlung des Kleingefüges bei Eisen und Kupfer durch Formänderung im kalten Zustande*.\*

Page 361: "In a pure metal the boundary between one crystal and its neighbour is not a definite sharp surface, which in section would appear as a single line, but that there is a certain space about the boundary in which the material belongs partly to one crystal and partly to the other, producing a narrow area of mixed orientation." So far as ferrite crystals without interposition of pearlite, and crystals of copper not in the cast state, are concerned, this assumption is entirely contrary to facts. The boundaries are so sharp that there can be no question of a boundary zone of mixed orientation. Perhaps Mr. Rosenhain



has arrived at his view through the following circumstance. When a specimen is deeply etched, as for instance with copper-ammonium chloride, all the grains are not attacked with equal rapidity. The writer has shown this in his paper on *Mikroskopische Untersuchungen an tief geätzten Eisenschliffen*.† The case indicated in the above diagram may then occur. *ss* is the original surface of the specimen. Let A and B be two ferrite grains respectively, with the boundary line CC. After etching, owing to the different rate of action of the copper-ammonium chloride on differently oriented crystals, the surface takes the form represented by the line *a'a bb'*. At *ab* the boundary then appears as a slope which must naturally show different etching figures than the faces *a'a* and *b'b*. This is probably the transition area of mixed orientation observed by Rosenhain. The paper above mentioned contains an exactly

\* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xliv. p. 503. † Berlin 1898.

measured example of such a case. If an etching fluid be used which does not give well-developed etching-figures, the slope *ab* appears as a double line.

Mr. F. H. NEVILLE (Cambridge) writes that he has read with much interest Mr. Rosenhain's paper. As to the earlier part, dealing with "slip-lines," he certainly thought that the evidence for Ewing and Rosenhain's views was conclusive, but it has occurred to him that Mr. Beilby's non-crystalline surface may have masked, in some of Mr. Osmond's experiments, the true character of the slip-lines.

Mr. Rosenhain's idea that the interlocking of different sets of skeleton crystals at the intergranular boundaries is an element in the strength of a metal, is well worth consideration, and might very possibly have important applications. In the case of metals or alloys whose final structure is that which arose during solidification, he thinks that Mr. Rosenhain's view is almost certainly correct, but in the case of steel or some of the bronzes the matter is not so simple. In these the substance, when just solid, consists of grains of an approximately uniform solid solution separated by a thin envelope of matrix, which in the case of steel will be richer in carbon than the grains: in the case of the bronzes this envelope is richer in tin. No doubt during the final stage of solidification the crystal systems of the grains interlock in the still liquid envelope of matrix. This process of solidification has its influence on the final structure seen in the cold metal; but that structure is, as we know, modified by the fact that as the solid metal cools, recrystallisation sets in in the solid solution. For steels with less than about 1 per cent. of carbon the new crystals are ferrite, while in steels richer in carbon they are the carbon-rich body cementite. Now, judging from what we know to happen in the bronzes, we should expect that the ferrite crystals in the steels with less than 1 per cent. of carbon would to some extent follow the orientation of the original skeletons first formed in the liquid, especially if the liquid had solidified rather rapidly. But the ferrite would not grow from the old boundaries of the grains, and these would not develop during the crystallisation of the ferrite. One would therefore expect the ferrite to have, on the whole, the same sort of interlocking as the original skeletons, and Mr. Rosenhain's



theory would apply to these steels. In the corresponding bronzes one sees a very complicated interlocking in the material that corresponds to ferrite (see Figs. 29 to 32 of the paper by Heycock and Neville referred to by Mr. Rosenhain).

But in the second group of steels, with more than 1 per cent. of carbon, he would (still reasoning from the analogy of the bronzes) expect the cementite to begin crystallising in the margins of matrix existing between the original grains of solid solution, so that these margins would become much developed into closed areas in the section of an ingot. The cementite would then invade the grains, growing out from the margins into each grain, but having a different orientation in each grain (see Figs. 46, 49, 49A, 50 in the copper tin paper). There would thus be an interlocking of the orientations of the final crystallisations of the different grains, but one very different in character and origin from that contemplated by Mr. Rosenhain. In the bronzes this latter kind of interlocking was a very weak one, and did not add to the strength, and he imagined the same would be true of steel.

Mr. JOHN PARRY (Ebbw Vale) writes that the author's observations on the plastic deformation of iron and steel appear to be of great importance, especially as they deal with matters intimately connected with practice, and as many of the facts investigated are common knowledge to practical workers in iron and steel. The knowledge of practical workers in this direction is, however, based solely on the empirical results of long practice. Mr. Rosenhain deserves our sincere thanks for a careful study of the phenomena observed, and his deductions therefrom throw considerable light on certain obscure results occurring in practice.

It is difficult to deal chemically with a material such as soft steel, containing say  $\frac{1}{2}$  per cent. of foreign matter, and although under the microscope it is possible to recognise certain compounds, the part played by the small quantities of foreign matter still seems an unsolved mystery. To this we must add the now accepted fact, that iron is subject to allotropic changes, and the further complications by the effects of physical conditions and works manipulations upon the formation of crystals, as so clearly indicated in Mr. Rosenhain's paper.

One of these workshop mysteries is the difference between wrought iron and steel, even when the two are of the same elementary composition: many have ascribed the difference to the fact, that wrought iron having never been actually fused, the impurities can only be eliminated mechanically by hammering, rolling, &c., while in the fluid state the metal is much more completely clarified. When these two forms of metal are mechanically treated, quite different results are obtained. What is technically called wrought iron persistently maintains the fibrous structure unless very wrongly treated. On the contrary, steel is persistently crystalline, and it is comparatively difficult to produce a finished fibrous material. Instances may, however, be quoted where these cannot be differentiated; so far as the writer's experience goes, both classes appear to be fundamentally crystalline, *i.e.* a bar of wrought iron, or a bar of soft steel, will show both a crystalline or a fibrous structure. A sudden sharp blow gives a crystalline fracture to the bar, slow blows and efforts to wrench without flaws, a fibrous fracture. Nevertheless it is more difficult to insure the fibrous fracture in the case of steel however soft than in wrought iron, thus showing that there is a fundamental difference which has hitherto, from a manufacturer's point of view, remained unexplained.

Strictly defining oneself, to the actual deformation of steel by mechanical treatment, there can be little doubt that the fundamental crystalline formation is retained, but it seems otherwise when the finished product is considered. For instance, in the writer's own experience, a rail with a crystalline head was required. This could only be obtained by hammering the blooms. Rolling resulted in a fibrous structure. It was found, however, that making the head of metal containing an extra percentage of phosphorus, the expensive and tedious process of hammering was needless. Similarly steel rails containing what may be termed high phosphorus percentage were best when rolled direct; in fact, they were cast near the section and rolled direct.

Finally, he did not wish to underrate the strictly scientific value of the elaborate researches now before us, but although himself a metallurgist and chemist, it is from the point of view of a practical worker of many years' experience that he has commented on Mr. Rosenhain's researches.

Mr. C. H. RIDSDALE (Middlesbrough) wrote that he had read Mr. Rosenhain's very excellent paper with great interest, and as physical metallography was a subject which he had himself for some years past investigated, and had on one or two occasions had the honour of bringing before their Institute some of his results as to flow-lines,\* and other effects produced by "slip" in soft steel, when deformed by rolling, forging, &c., whilst at various degrees of plasticity,† he had pleasure in taking part in the discussion.

He was gratified to find from the results Mr. Rosenhain now gave them after having repeated and amplified the bases of the conclusions which he had in conjunction with Professor Ewing arrived at, and laid before the Royal Society in 1899, that the views he (Mr. Ridsdale) had himself set forth in the same year not only remained uncontroverted, but were abundantly confirmed; and he was the more gratified because, at the time he published them, he was quite unaware of the work they had done on the same subject, and it was only later that Mr. Stead had called his attention to it. Working quite independently, they had necessarily approached the subject from somewhat different standpoints, but it was remarkable how much of the same ground they had both traversed, and how closely the points touched in common agreed, which, however, he must not stay to enumerate.

Mr. Rosenhain had traced in a very beautiful way the manner in which flow occurred in the crystalline grains, and was revealed by slip-bands when either plain polished or *previously etched* samples were strained, but had explained (pages 356, 357, and 358) that after repolishing no trace, or only slight traces, of these were left, and hence were not available for detecting whether material was already strained.

He had also (p. 341) said a little about the indications of flow left in *previously strained* metal, and he (Mr. Ridsdale) would be glad if Mr. Rosenhain could add anything further to this, as issues which arose were generally with reference to metal which

\* "Flow-lines marking the direction in which the material has slipped." "Practical Microscopic Analysis," *Journal of the Iron and Steel Institute*, 1889, No. II. p. 119.

† At blue heat and cold. *Ibid.*, particularly pp. 120-123. At all temperatures from the moment of setting, through red, low red, blue heat, and finally cold. "The Correct Treatment of Steel," *ibid.*, 1901, No. II, particularly pp. 66-72.

had been *already strained*, and in such cases practical men were chiefly concerned with how they could be sure whether or not flow had been conducted under such conditions as had left the material in a damaged state. For this reason his (Mr. Ridsdale's) own work as to blow had principally been in this direction, and as he had endeavoured to arrange all the information available in a system of tests,\* he should be glad if Mr. Rosenhain could suggest anything further.

As regarded the elongation of crystal grains in mild steel which had already been subjected to cold rolling or hammering, seen in sections, "so taken that the direction of the deformation lies in the plane of the surface . . ." (p. 341). This was the case also to a large extent in steel in which work was finished at the ordinary (hot) rolling temperatures, as he (Mr. Ridsdale) had himself shown.†

As regarded the curvature of slip-bands in ferrite being due to the crystals having formed in a solid solution (p. 345), he thought Mr. Rosenhain's explanation was very reasonable, and most probably correct.

*Re* the splitting action of shock within the grain itself, and the statement (p. 350) that Messrs. Osmond, Frémont, and Cartaud considered that "under all circumstances deformation of ferrite crystals can only take the form of actual fracture," whilst he (Mr. Ridsdale) did not believe this, he did think that inter-crystalline slips might occur beyond the limits of natural restoration, and indeed there might be *intercrystalline* fracture within some of the grains along the line of flow, just as there was *intergranular* parting, the whole causing what he had termed "incipient rupture."‡ He thought the retention of brittleness for long periods by samples § which had undergone considerable

\* "Diseases of Steel," *Journal of the Iron and Steel Institute*, 1902, No. II.

† "Practical Microscopic Analysis," Fig. 4, Plate III., *Journal of the Iron and Steel Institute*, 1899, No. II.

‡ "The Correct Treatment of Steel," *Journal of the Iron and Steel Institute*, 1901, No. II. p. 68. "Internal strains more or less nearly equal to the extent of its endurance and which may be termed *incipient rupture*, are set up, and actual rupture between or in many of the grains frequently occurs." Also "Practical Microscopic Analysis," *Journal of the Iron and Steel Institute*, 1899, No. II. p. 120, "Brittleness . . . due to . . . more or less complete rupture of a number of *individual* granular junctions or *cleavages*, developing sometimes into continuous cracks."

§ *Ibid.*, p. 121.

deformation, but did not exhibit intergranular separation, were due to this.

In this connection he thought that in experiments upon fatigue effects, not only the rate of reversal (p. 354) was an important factor, but also (as he had found when bending bars held at one end backward and forward, as described by Professor Arnold) that a slight variation in the *extent of deflection* produced altogether disproportionate results.

Mr. Rosenhain (pp. 358–362, &c.), in seeking for “the mechanism of the very powerful cohesion between adjacent crystalline grains,” had been led to recognise the important part played by the interlocking of the crystal boundaries, and speaking of the effect of forging at a time when recrystallisation was taking place, had said it might be to cause increased interpenetration, and that “it is possible that such an action may lie at the root of the well-known improvement of mechanical properties which results from forging under proper conditions,” and he had quoted confirmatory evidence from lead.

He (Mr. Ridsdale) could assure Mr. Rosenhain that it was precisely because he had found that samples which actually exhibited great toughness did show an interlocked structure of a type similar to Fig. 21, and that others which were less tough more nearly resembled in type Fig. 20, that he had come to the conclusion that toughness was a function of interlocking rather than mere adhesion of the grain, and he had in consequence made the statement, “Toughness depends on *cohesion* of the grain,”\* and had repeatedly strongly emphasised the importance of applying work in such a manner that “the grain is broken up or elongated, kneaded and interlocked, and the material thus becomes tougher, being *dovetailed* as well as stuck together.”†

In this connection, and with reference to the space about the boundaries in which the material belongs partly to one crystal and partly to the other (p. 361), and also to the effect of mechanical pressure “at a time when recrystallisation is taking place” (p. 366), the examination of good welds was most in-

\* “The Correct Treatment of Steel,” *Journal of the Iron and Steel Institute*, 1901, No. II. p. 69.

† *Ibid.*, pp. 66, 67.

teresting, and formerly independent grains might be seen to have united, the recrystallisation and interlocking showing perfect continuity right across the line of weld.

*Re* the double boundaries between ferrite grains (p. 363), he had often observed these.

Mr. Rosenhain had said (p. 365): "It is, then, a matter for further investigation to discover that method of heat and mechanical treatment which, while keeping the size of the crystalline grains themselves as small as possible, will result in the greatest amount of interpenetration." He (Mr. Ridsdale) thought the best method was continuing work (where practicable) down to a low red heat—as low as was possible without setting up permanent strains, which would counterbalance the good effect.

There were other points which he would like to have touched on. He congratulated Mr. Rosenhain on having given them a paper affording much food for thought, but it was impossible to discuss it thoroughly without exceeding the permissible limits.

Mr. W. ROSENHAIN wrote that with regard to Professor Ewing's remarks on the presence of eutectic-forming impurities in the interstices left by the interlocking arms of adjacent crystals, there could be no doubt that, where these existed, they would play an important part in keying the structure together. On the other hand, as Professor Ewing himself pointed out, in the case of re-crystallisation in a solid, the segregation of these impurities to the boundaries would not so readily occur, while even in crystallisation from a liquid, minute quantities of impurities would probably be locked up between the dendritic arms within the mass of the crystal itself. Although, therefore, the eutectics might play an important part at the boundaries when present there, it was an important feature of his theory of interlocking that the inter-crystalline cohesion did not necessarily depend upon any cementing material in the boundaries, eutectic or otherwise.

In regard to Mr. Neville's views on high-carbon steel, he would point out that he specially stated that his theory was intended to apply to pure, or nearly pure metals, so that he

had not considered the question of interlocking between crystals of cementite in high-carbon steels.

With regard to Mr. Neville's suggestion that the presence of Mr. Beilby's non-crystalline surface layer might interfere with observations of slip-bands, he would point out that these observations are generally made upon metal which has been etched after polishing, so that, in those cases, the surface layer would have been removed. In some cases, and this bore out Mr. Neville's idea, it was found that the slip-bands could not be so clearly observed if the section had not been previously etched.

He was particularly glad to see Mr. Parry distinguish between "crystalline structure" and "crystalline fracture"—the two were very frequently treated as identical, which was very far from being the case. The character of the fracture of a given piece of metal is in reality a very unsafe guide to its structure, for while the structure no doubt has an influence upon the appearance of the fracture, that influence only becomes predominant when the structure is of a very special character, as in very hard or very brittle metals in ordinary cases he believed the appearance of the fracture depended, as Mr. Parry pointed out, chiefly upon the nature and distribution of the stress which caused the fracture. The only safe guide to the structure of the metal is a micro-section, and the evidence of the microscope proves that metal is always crystalline, and never really fibrous; the only approach to a fibre in the case of annealed wrought iron being the long threads of cinder which follow the direction of rolling, while in commercial material there is often a slight approach to a fibre by the elongation of the majority of the crystals in the direction of rolling which arises from a slight amount of "cold rolling" due to a low finishing temperature. The former species of fibre occurs, of course, in wrought iron alone, while the latter is common to iron and soft steel.

In regard to Mr. Ridsdale's remarks, he (Mr. Rosenhain) was particularly interested in the various confirmations of his views and observations which they contained. The recognition, microscopically, of the effects of past plastic deformation, was a subject of great difficulty, but the paper of MM. Osmond, Frémont, and Cartaud, to which he had such frequent occasion to refer, undoubtedly marked a step forward in this subject.

He himself was at present unable to add anything on this point, but hoped, as he had indicated in the paper, that it might ultimately be possible to utilise the shape and character of slip-bands produced by a definite amount of deformation, to judge of the internal character, and to some extent the past history of the specimen.

In reply to Professor Heyn Mr. Rosenhain considered it evident that the Professor had been under considerable misapprehension as to the facts and ideas contained in the present paper. Professor Heyn's impression that the author desired to push the generalisation as to the effects of slip further than formerly was entirely unfounded. If Professor Heyn would refer to Paper A., p. 372, he would find the conclusion there stated to be that "plastic yielding (is) due to slips on cleavage planes within each individual crystalline grain, and in some metals to the production of twin crystals." That conclusion embodied all that Professor Heyn was contending for in the first section of his letter. It was true that the production of twin structures by deformation had not been specially referred to in the present paper, but the reason was simply that this aspect of the slip-bands theory had not been attacked by the French authors referred to in the paper. The claim for priority for Mügge's work which Professor Heyn seemed to advance, he (Mr. Rosenhain) did not consider it desirable to discuss in detail, but it was only fair to point out that the discovery of slip-bands by Professor Ewing and the writer was entirely independent of the work of Mügge; that investigator's work was, moreover, in its early stages of a purely mineralogical character, and concerned native crystals of such metals as gold and bismuth. Mr. Rosenhain believed that the generalisation stated in the conclusion quoted above was given for the first time in the place referred to.

The letter by Professor Heyn left one in considerable difficulty in deciding what were the Professor's exact views on plastic deformation. In one sentence he emphatically disclaimed the view that the crystalline elements themselves were deformable, while in the very next he considered that "a fan-like alteration of shape of a crystal" had taken place, and this last statement seemed to imply that the change of shape had been due to



causes other than slip or twinning, and Professor Heyn advanced no other mode of deformation as an alternative.

Professor Heyn's statement that in a large number of specimens he had not found the slight variations of orientation within individual crystalline grains of iron, he (Mr. Rosenhain) was prepared to accept as strong evidence against the supposition to that effect which he had advanced in the paper; such suggestions were always open to the correction of experiment, but in justification of his suggestion he (Mr. Rosenhain) would remark that such variations of orientation had been found in crystals of tin-plate (Paper B) and lead (see paper by Ewing and Humfrey). In iron the variations, if they existed at all, would be very slight, and although Professor Heyn's negative evidence was valuable, it could hardly be conclusive.

Mr. Rosenhain was much surprised by Professor Heyn's account of the appearance of slip-bands in ordinary iron or low-carbon steel. It appeared to him that if deformation of the crystalline elements took place at all it would be extremely unlikely to do so *before* slip took place, or rather that, deformation of the elements having once taken place, slip should occur at all, since in the deformed crystals slip could only occur with much greater difficulty than in the virgin crystals when deformation first began. Moreover Mr. Rosenhain and Professor Ewing had very carefully tested this particular point in 1898-99. They had attached a microscope to bars under test in a testing-machine, having previously polished a large area on one side of the bar, and they found most definitely that in all the specimens they examined the slip-bands appeared as soon as plastic deformation reached that part of the bar which was under microscopic observation. Professor Heyn's observations were apparently in direct contradiction to these, and there must be some explanation of the discrepancy. This may perhaps be found in the fact that in Professor Heyn's specimens "ferrite grains had emerged from the surface, and rendered it rough;" it is possible that by being thus bodily displaced these crystals were saved from actual deformation in the earlier stages of the test. It must be remembered that all we can observe are slip-bands on the outside layer of crystals, and it is quite conceivable that under some conditions yielding by slip may go

on to some extent within the mass of the metal, leaving the outside crystals comparatively unaffected at first. No doubt the rate of applying the load might affect such a phenomenon, and could account for discrepancies between different observers.

Professor Heyn's observation that in seriously over-heated iron the slip-bands were "perfectly straight" was a striking confirmation of the view as to the cause of the curved bands in ordinary iron advanced in the present paper, since in such over-heated iron we had a metal in which, if crystallisation had not exactly occurred from a fluid, at least the eutectics had been liquid and the molten state had been closely approached by the entire metal.

Professor Heyn appeared indignant at the apparent neglect of Mügge's work, but it must be remembered that the work of Mügge, however valuable, is not at all readily accessible to English readers, and his work on isolated crystals has been carried out from a standpoint very different from that of the metallographer, so that it might still be permissible to think that further work was required. The sentence in the paper to which Professor Heyn took exception was, moreover, intended to express the view that the work described in the French paper referred to was not sufficient to justify theoretical conclusions.

The frequency or otherwise of twin structures in iron is not a point vital to the argument of the present paper, but the author had not arrived at his conclusion merely from the examples briefly referred to in the paper. It would perhaps have made his position clearer to state that, having once observed a few well-defined cases of twin-structure in iron, he (Mr. Rosenhain) now regarded a number of appearances which were frequently to be found in iron, particularly after deformation, as evidences of twin structure. The author intentionally left it an open question whether these twin structures had existed prior to the deformation or had come into existence during the experiment.

Finally, Professor Heyn wished to sweep away the entire theory of dendritic interlocking between crystals. Mr. Rosenhain regretted that Professor Heyn was unable to attach greater weight to the ideas and evidence which had been brought for-

ward in the present paper. The diagram by which Professor Heyn sought to explain away the double boundaries illustrated in the paper was, however, entirely insufficient. The fact that etching agents attacked differently oriented crystals at different rates has been familiar to metallographers for a very long time. That it was familiar to the author, who would thus be unlikely to be misled by appearances arising directly from it, may be proved by referring to Paper A, p. 355, "the boundaries between them (the crystals) have been made evident by the differential action of the acid, which has produced differences of level by attacking one grain more energetically than its neighbour. Each of the short sloping surfaces which connect one grain with another appears black because it does not reflect the normally incident light back into the tube." It is, in fact, this latter appearance which a configuration in accordance with Professor Heyn's diagram could alone give. The remark that etching fluids like nitric acid do not give well-developed etching figures apparently implies that therefore their indications are not reliable; such an attitude, however, he (Mr. Rosenhain) could not regard as logically correct, since the indications of each etching medium should be investigated on their own merits, and while copper-ammonium chloride, no doubt, gave good etching-figures, it was not a suitable medium for the investigation of boundary conditions. Professor Heyn's remark that the etching-figures on the sloping boundary surface in his deeply-etched specimens were naturally different from those on the faces of the crystalline grains, showed that the Professor had not fully realised the author's meaning in reference to the "narrow region of mixed orientation." According to the author's view, if it were ever possible to see etching-figures at all on so narrow a surface as that between double boundaries, these etching-figures would consist of two interspersed systems, each set following the orientation of one of the interlocked crystals.

Mr. Rosenhain regretted that he had been placed under the necessity of traversing the contentions of so eminent a metallographer as Professor Heyn, but the attitude assumed by the Professor left no other course open.

## THE USE OF STEEL IN AMERICAN LOFTY-BUILDING CONSTRUCTION.

By B. H. THWAITE, Assoc. M. INST. C. E. (LONDON).

### INTRODUCTION.

IN a lecture delivered last year before the British Academy, Professor Atchison drew attention to the neglect of British architects to take full advantage of the structural merits of steel and of iron. He, however, laid some stress on the disadvantages associated with the use of steel if compared with masonry and timber. For instance, he referred to the dilatation factor, the shrinkage by contraction, the moisture on iron in damp weather, the peculiar properties of both iron and steel when exposed to flames, their inartistic proportions, owing to the great compressional strength they possess compared with masonry or timber. All these disadvantages have not, however, deterred American builders from raising steel and iron to the position of supremacy as the element of strength, in the service of modern American building construction, both masonry and timber taking a very subordinate position as essential elements of construction; and to-day, in North America at least, the great iron and steel industry finds in city and town building operations, a considerable and widening source of demand for iron and steel manufacturing products.

Certain it is that but for the life-work of two former presidents of the Iron and Steel Institute, Bessemer and Siemens, to the encouragement given to the system of construction by the present president, Mr. Carnegie, and his steelworks staff, and to other American metallurgists, the main principle of construction of the lofty buildings that gives the skyline of Lower New York such a characteristic appearance (Fig. 1) would not have been found practicable, or even if practical, the cost would have made the application financially impossible.

The evolution of the art of lofty construction of tiers of storeys could not have been possible, had not mild steel joists been available of the highest quality, and at a reasonable price,

and had not the perfection of elevator, or lift construction, permitted occupants to reach their floors with safety, rapidity, and without inconvenience.

### EARLY HISTORY.

Mr. Purdy, who has designed some of the most striking examples of steel-frame construction, explained to the author, during his recent visit to the United States, that the credit of

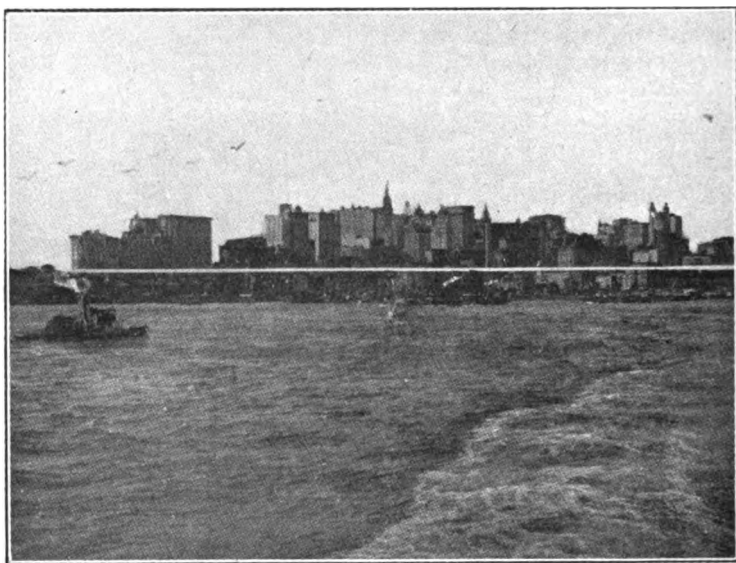


FIG. 1.—The white line is above the skyline of New York a few years back.

the basis of this steel-frame construction really belongs to English engineers ; and he is right.

In the author's work on *Fire-resisting Factory Construction*,\* published twenty-two years ago, the early history of the system is briefly set forth. It appears that in the fifties Mr. Pritchett, a Yorkshire architect, designed a Retreat, belonging to the Society of Friends, which was constructed in the ancient city of York, in which he embodied iron girder and brick arch floor ; so that

\* "Our Factories, Works, and Warehouses ; their Fire-resisting Construction," 1882. By B. H. Thwaite. Published by Spon : London and New York.

if New York has been embellished and structurally ennobled by the steel-frame system, the ancient city of York probably possesses the first actual example of the basis of the system, for which we are also under obligation to Sir William Fairbairn, who applied iron joists and intervening hollow brick arches to form the floors of the Saltaire Mills, Saltaire, Yorkshire (Fig. 2).

Sir W. Fairbairn's application of iron to building operations was improved upon by Whichcord, a British architect, who was the first to apply, in 1873, a refractory or fireguard encasement to the bottom flanges of the iron girders (Fig. 3): this system was employed in the construction of the National Safe Deposit Company's building. Hornblower, a Liverpool architect, extended, in the early eighties, the hollow and flat arch system. The author was well acquainted with this ingenious construc-

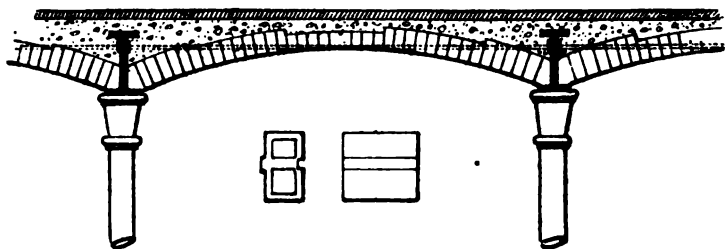


FIG. 2.—Details of arch bricks.

tionalist, whose system of floor construction is nearer to the most modern methods of American construction than that of any other British pioneer (Figs. 4 and 5).

In any general history of the evolution of the use of iron and steel one must not forget the work of the talented designer of the 1851 Exhibition building, which, under the title of the Crystal Palace, constitutes a magnificent memorial to the engineering glories of the Victorian era, and to the value of iron as a structural element.

Later and more modern developments, from the date of the early eighties, had their home in the United States, and from amongst the group of workers and pioneers two men deserve conspicuous mention, one of whom, Col. Wm. B. Jenney, of Chicago, may be considered to be the father of the American development of the steel and iron frame system of construction,

in which the steel frame supports everything, the skin or outer walls, the floors, and the roofing. By Jenney's pioneer work steel and iron were made the essential component elements of construction.

To another Chicago architect, Mr. W. H. Burnham, credit is due for the novel method of the grille foundation construction system, that safely permitted tier upon tier of storeys to be

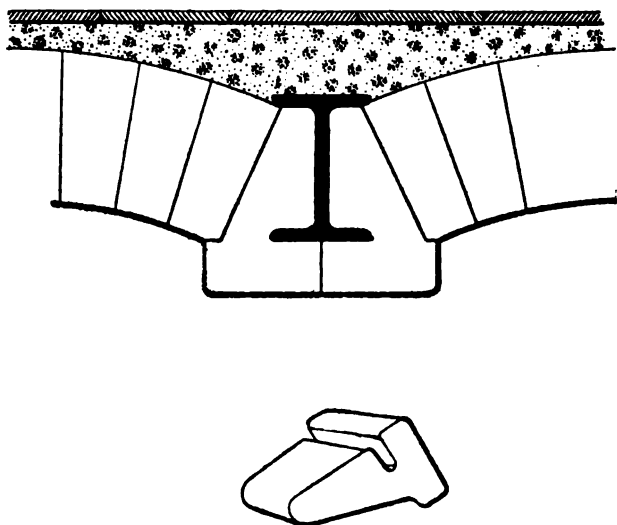


FIG. 3.—Detail of Girder Encasement.

built, making up an aggregate weight of thousands of tons of superstructure, without danger of serious or irregular settlement.

#### THE AMERICAN DEVELOPMENT.

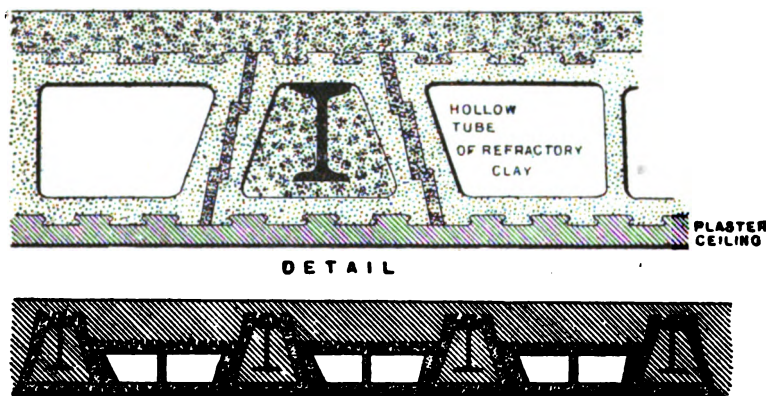
The pioneer application of Mr. Burnham's invention was that of the foundations of the walls of the ten-storey Montauk block, constructed in 1882 in Chicago, and which were carried on railway rails arranged in parallel or *grille* form. A modern example of grille foundation construction is shown in Fig. 6.

A year later, or in 1883, Col. W. L. B. Jenney designed the ten-storey Home Insurance building of Chicago. This building partially embodies in its design the fundamental feature that differentiates the system from earlier and British methods of construction. In

this structure the weight of the floors, the roof, and the outside walls is more or less completely carried by the iron framework; in this Home Insurance building (Fig. 7), cast iron columns constitute the vertical elements, and W.I. beams carry the floors.

A later building, the Rookery, eleven storeys high, was erected in Chicago in 1885 and 1886. The vertical columnar supports had isolated footings on the Burnham system, but the outer masonry walls carried part of the floor load.

The first really complete application of the principle of steel-frame construction is embodied in the fourteen-storey Tacoma building, built after 1886 from the designs of Messrs. Holabird & Roche. This construction constituted an epoch in Ameri-



FIGS. 4 AND 5.

can architectural history, and in the evolution of the use of steel and iron in building construction.

Since this date (1886) the steel-frame element has attained supreme importance, architectural features becoming questions of subordinate value.

As the buildings attained higher and higher altitudes, the question of the effect of wind pressures had to be faced, and most ingenious methods of wind bracing, involving a still further increase in the use of steel, have been devised; the earliest serious attempt to structurally face the problem of wind pressures is probably the one embodied in the extension



of the Reliance building in the year 1894. The characteristic feature of the system, known as the table-leg wind-bracing method, consists in making each floor rigid in itself, deep plate girders connected by vertical splicing plates to the columns, and not by merely being hung bolted to brackets; these plate

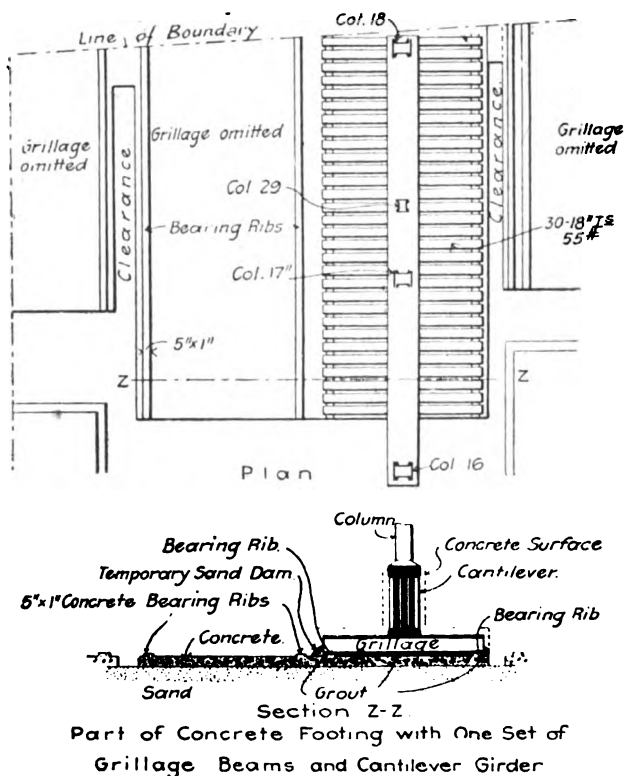


FIG. 6.

girders connecting all the outside columns constitute the origin of the title, the Table-Leg Principle.

#### THE RATIONALE OF THE SYSTEM.

We know that the use of steel, the conspicuous feature of the system of construction under review, has permitted floors to be superposed over floors to an extent never dreamt of as possible



**FIG. 7.—Home Insurance Building, Chicago. The first building in the world to use steel skeleton framework in its construction. Absolutely fireproof.**

by orthodox masonry constructionalists. Now the extension of height involved in the tiers of stories may reasonably prompt the question, *Cui bono?* The reply can be found in the constant tendency of modern civilised life towards concentration of effort and energy; and in no direction is the tendency more marked than it is in business methods and in business centres, and the result is that ground space in these centres of business activity has attained almost phenomenal value. In many cities the ground space of the business area is concentrated on these contracted areas, which cannot be extended. Now every additional floor added to an office, warehouse, or factory, means the duplication, more or less completely, of the ground area on which the building stands. The effect of the steel-frame system, in raising the normal number of storeys from five to twenty, is equivalent to the addition to the business area of Manhattan Island, New York, of some 200 acres of habitable land—probably representing an increased yearly rental of 1½ millions sterling. The ground floor unit of cost of a twenty-storey building is only one-fourth that of a five-storey building, a statement only requiring the qualification that the foundation, grille, footings of steel of the former will cost more than that of a five-storey building. But although the highest qualification in favour of the steel-frame system of construction is embodied in the fact that it has extended the safety limit of building height by an additional twenty storeys, the system is now being applied to structures of the height usual in Europe, and within the limits controlled by building regulations of European and British cities;\* but the author trusts that his explanation of the rationale of the system

\* *An Essential Condition of Success.*—As a rule all the steel-frame buildings erected under the supervision of the expert engineers are designed with most conscientious care. The author was surprised with the thoroughness with which all the proportions were calculated to satisfy exigencies of variable loads, to secure safety from settlement, from fire effects, and from the influences of wind pressures. The methods of calculation and the average precautions taken would satisfy the most cautious of British engineers; yet at the same time clauses safe-guarding the public against the jerry-builder of steel structures ought to be inserted in the building regulations of the cities of the United States. The steel-frame system of building, of so much interest to iron and steel makers, has suffered by the action of unscrupulous builders who are sufficiently dishonest to prefer to paint imitation rivets and use girders of inadequate strength. Such unscrupulous work has already proved fatal to men's lives in the United States, and constitutes a warning for those responsible for the framing of the

will tend to induce the Iron and Steel Institute to use its influence in removing the British and European restrictions that prevent the full advantages of the new system from being secured.\*

The increase of office accommodation by the construction of the lofty steel-frame buildings has brought down the rents of offices and warehouses; for example, the charge for offices in the old buildings of 12s. per square foot has been reduced to as low as 6s. a square foot, a price that includes conveniences and advantages that did not exist in the old offices.

It will be realised that a substantial reduction of rent, along with the additional and splendid advantages and conveniences provided, makes the new system a positive boon to the city worker. That the system may also be profitable, as it deserves to be, is proved by the following comparison:—†

*A Comparison on the same Site of a Four-Storey Building and a Sixteen-Storey Building, with two Lower Floors Banking Premises.*

	FOUR-STOREY BUILDING.	SIXTEEN-STOREY BUILDING.
Renting Area	6000 sq. ft. per floor 24,000 sq. ft. of floor area, exclusive of ground floor	7000 sq. ft. per floor 105,000 sq. ft. of floor area, exclusive of ground floor height of two storeys.
Rent per sq. ft.	\$3, or 12s. 6d. per sq. ft. average	\$1·66, or 6s. 8d. per sq. ft. average
Annual gross rent potential	\$70,000, or £14,533	\$188,000, or £39,666
Interest on capital	possible 4-5 per cent.	possible 12 per cent. ‡

building regulations of our cities, which should be extended so as to permit the system of steel-frame building to be utilised, but with such stipulations as will secure the full and proper application of all the science and experience now available.

\* The height of buildings is restricted in some of the American cities, although in others a man may build any structure he pleases on the lot he owns. There are no laws respecting light, except for certain classes of buildings.

† As 4 per cent. mortgages can be raised on steel-frame structures for 60 per cent. of its value, the net return on a well-located, well-designed, and well-built steel-frame structure should be very satisfactory. Construction companies, such as the Fuller and Edgar Thompson Companies, arrange with owners of existing dwarf buildings, in good position, to rebuild on the steel-frame principle, offering a 2 per cent. increased profit over the returns from the dwarf buildings. The Construction Company retains the excess interest.

‡ It is generally assumed that the greatest ratio of return to expenditure in lofty steel-frame construction is obtained from buildings of sixteen to seventeen storeys, but the twenty-storey buildings are the most popular.

## IMPORTANT FIELD OF APPLICATION FOR STEEL AND IRON.

The field of application of iron and steel in the steel-framed building operations has assumed very important dimensions. It is one that is rapidly extending, and that the effect of the irresistible law of the survival of the fittest will become evident here, will be the opinion of metallurgists and engineers who have the privilege of the experience of seeing the system for themselves in the great cities of the United States.

The proportions of the steel-framed building demand for steel in the United States are increasing. It may with sufficient accuracy be assumed, that on the average of the last five years some 200,000 tons of steel and iron are absorbed in steel-frame construction in the United States per annum.\*

The weight of steel in the ordinary office type of lofty building will average from 1.5 to 2 lbs. per cubic foot of building. The average weight per square foot of a steel-frame (entire) structure, carrying both outside walls, floor, and roof, may be taken to be equal to 22 lbs.†

The following table gives some examples for reference:—

Number of Storeys.	Weight of <i>Steel Framework</i> , Entire Structure, per Square Foot of Building.	Name of Building.
Eleven	17 lbs.	Maritime Building, N. Y.
Eighteen	23 ..	Maiden Lane Building, N. Y.
Twenty	22½ ..	Whitehall Building, N. Y.
Twenty-five	29 ..	Wall Street Building, N. Y.

The total weight of steel and iron in steel-framed structures of normal proportions (say, 18 storeys, and 6000 to 7000 square feet) will vary according to depth of foundations, between 1200

\* Figures for which the author is indebted to Colonel Hunsiker.

† Owing to the variation in the weight of columns for the different storeys, and their changing cross-sectional area, for the different storeys corresponding to height of building, it is impossible to give the weight of steel and iron used in a steel-frame building per square foot for each floor.

But it can be approximately calculated by the formulæ:—

When  $F$  = the square feet of floor

$N$  = the number of floors, including roof

Then  $15 NF$  = weight of beams and fittings in buildings in lbs.

$7 NF$  = weight of columns in buildings in lbs.

and 2000 tons; exceptionally proportioned buildings have absorbed some 7000 tons of steel and iron in their construction.\*

For instance, the New Land Title building, erected in Philadelphia, is said to have absorbed 7000 tons of structural steel in its construction (Fig. 8).

The New Hotel Astor, New York, although only ten storeys in height, will absorb 4000 tons of structural steel.

The Hotel Belvidere, Baltimore, having a total foundation to roof height of 218 feet, has absorbed, it is said, some 2400 tons of structural steel.† In this new structural development the American iron and steel industry has indeed found a friend. Shall the friendship be extended to cover, in its benefits, the iron and steel workers of Europe and Great Britain?

It is, moreover, worth while to remember that, except a cataclysm occurs, the structural steel and iron in a modern lofty steel-frame structure is put out of the markets of the future, once it is embedded in the walls and frames of a building; and such steel cannot therefore (as do many other products of a steel-works, for example, the constructional steel used in railroads, light portable constructions, &c.) come into the market again to compete with new iron and steel products.

The absorption of steel and iron in steel-frame structures is, however, not confined to the foundations, columns, floors, and roofs, as the following particulars (for which the author is indebted to Mr. R. P. Bolton, C.E., of New York) abundantly prove.

Ordinary steel-framed structures absorb in their sanitary, water-supply, heat, hydraulic power, gas, and electric conduits, some 15 miles of piping. Larger structures absorb 20 to 30 miles' run, and hotels and apartment structures absorb considerably more: the pipes average in weight from  $3\frac{1}{2}$  to 4 tons per mile run.

In the Anconia Apartment, steel-frame structure, New York, there is, according to Mr. Bolton, no less than 205 miles of all kinds of piping, ranging from 16 inches to  $\frac{1}{2}$  inch

\* The Park Row building, New York, is said to have absorbed in its structural framework no less than 9000 tons of steel.

† The proportion of steel absorbed in a 15-inch hollow tile arch floor, and having a total weight of 75 lbs. per square foot, will be some 13 per cent. of the total weight.

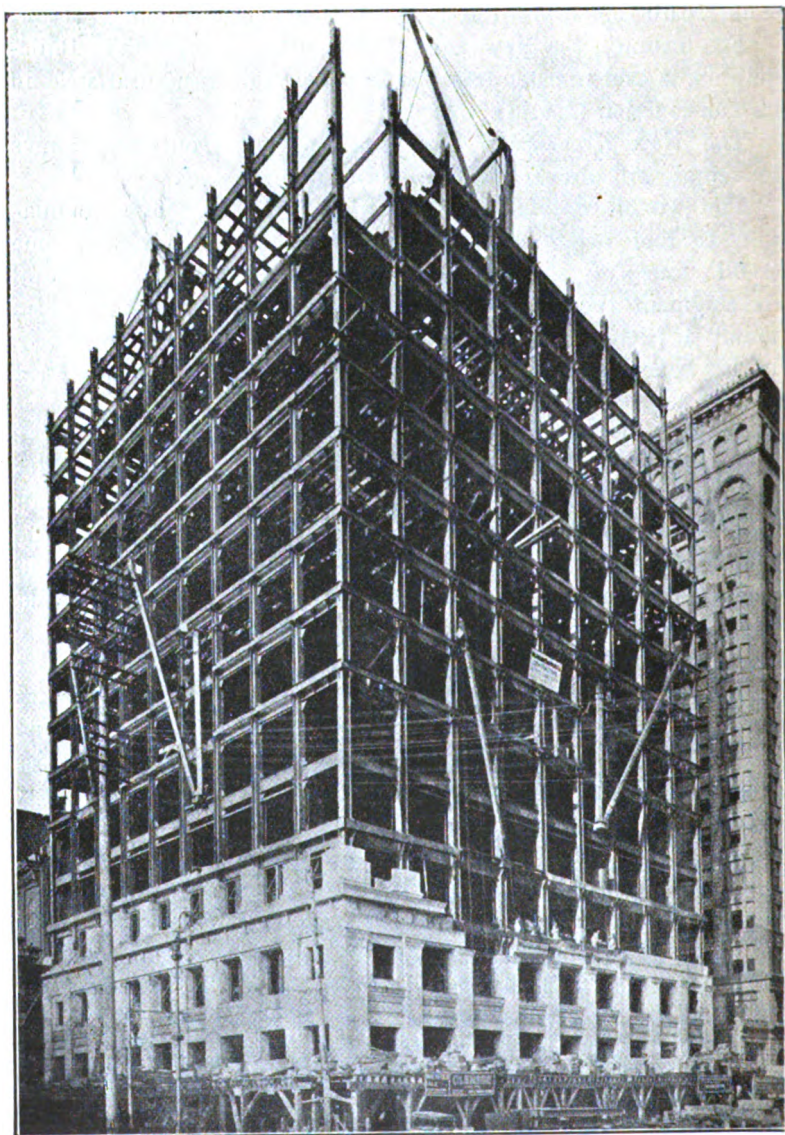


FIG. 8.—The Land Title Building, Philadelphia, during erection.

diameter. The sanitary, hot, and cold water equipment of this building absorbed nearly 16 tons of screwed fittings, elbows, tees, &c., and many thousands of valves were used in addition.

Besides the piping, steel and iron in some merchantable form is absorbed in the construction of tanks, pits, vents, drums. There are the lofty smoke-stacks of steel or W. I. plate. The smoke-stack of the Anconia building varies from 6 feet to 2 feet 6 inches diameter, and is 300 feet in height, made of plates  $\frac{5}{8}$ -inch to  $\frac{1}{2}$ -inch thick. The smoke-stack of the Bowling Green building, New York, is 225 feet high; has an area of 28 square feet, made of plates varying between  $\frac{3}{8}$  and No. 8 W.G.

The absorption of steel in the mechanical equipment of steel-framed lofty structures will perhaps be understood when the proportions of the machinery required for working the elevators or lifts, and providing the steam heat, is defined. Here are some examples:—

The boiler power of the—

1. Bowling Green offices with 9 hydraulic lifts=720 horse-power.			
2. R.G. Dun building	6 electric	=600	..
3. Hudson	4 hydraulic	=500	..
4. Central Bank building	5	=460	..
5. Lords Court	5 electric	=420	..
6. German American	5	=320	..

The lift or elevator car miles per hour varies from 8 to 20.

The number of electric lights varies from 2800 to 6200.

According to Mr. Bolton, the mechanical equipment of a sixteen-storey steel-framed office building, basement and sub-basement, of, say, 6000 square feet of renting area per floor, will cost some £17,000, of which the component parts are made up as follows and given in percentage of cost:—

34.5	per cent.	cost of lifts or elevators—4 in number.
17.3	..	.. steam heating appliances.
14.0	..	.. sanitary arrangements.
11.7	..	.. electric wiring and switchboard.
11.0	..	.. boiler plant.
10.0	..	.. engines and generators.
1.5	..	.. chimney.

The mechanical equipment of a first-class steel-frame structure includes the provision for ventilation, heating, fire protection, refrigeration, electric lighting, telephone, and electrical services—



power provision for lift or for elevator service—all requirements involving in some measure the use of steel and iron.

#### IMPORTANCE OF THE KNOWLEDGE OF THE SYSTEM ON THE PART OF THE IRON AND STEEL MANUFACTURER.

In the United States the new system has practically revolutionised the professional constructional organisation, the engineer, steel framework designer, and the ironworks have partially displaced, for the constructional services, the architect and the timber-yard. The engineer and the architect have joined forces with the happiest results—science and æsthetic art being thus associated. The new system of construction has not been adopted in Great Britain, except in a very tentative way, and for buildings of some four to five storeys only.

An examination, whenever an opportunity occurs, of the details of the steelwork structural system will soon convince iron and steel makers that they will probably benefit by becoming interested in watching and aiding the new development, which puts their product on such a high plane of utility.

The steel-framed structural system permits a considerable part of the mechanical work, involved in fitting together the different elements, to be carried on at the iron or steel works. This is the method adopted in the United States.

The mechanical work of fitting is divided into two branches, differentiated by the terms shop and field work.

The diagram, Fig. 9, shows the graphic method of defining which is shop and which is field work. The columns, brackets, gussets, and other steel support attachments are as far as possible riveted up before they leave the manufacturer's works, girders are cut to length, and all holes cored, drilled, or punched; in fact, every part of the work is designed to secure rapidity in working constructions with the minimum degree of transport, &c. When the steel columns and girders arrive at the site,\* they are then ready for immediate attachment,† the

\* Each storey bears its own weight.

† It is Colonel Jenney's practice to have the beams and other structural metallic elements simply oiled and painted at the mill, as all assembling of the steel elements is done with hot rivets; most of the painting is done after erection.

The scheme of distribution of weight is both scientifically and mathematically true. Each supporting column is designed to bear a specific weight, sometimes as much as 3,000,000 lbs.

result is a speed of erection that to Europeans appears to be little short of marvellous. The examples presented of the rapidity of construction are sufficiently convincing; a twenty-storey building may be erected in less than six months; buildings have been erected at the rate of one storey complete in a fortnight.

The objections raised against the use of steel by European architects challenge the consideration of the members of this Institute. It will, however, be realised on a close perusal of this paper that the difficulties enumerated by Professor Atchison,

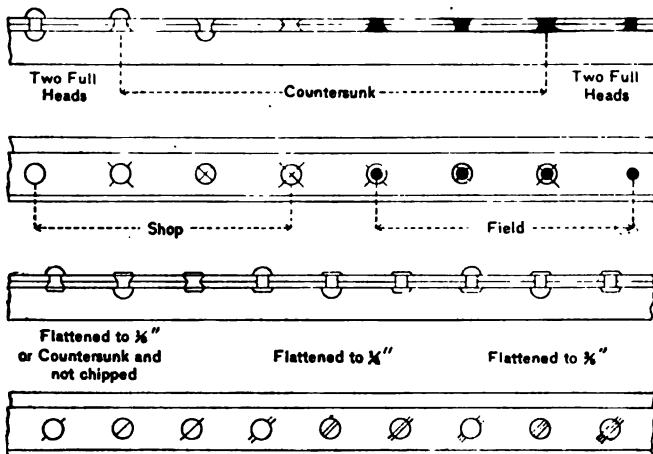


FIG. 9.—Conventional signs for riveting shop and field work.

and which, if not removed, will tend to deter British and European architects from following the bold lines of construction laid down by their American brethren, are after all more imaginary than real. For instance, it is found—

(1) That the dilation of the curtain, or covering masonry and brickwork, and its joints, as well as the concrete, constituting the non-metallic elements of the lofty frame structures, corresponds sufficiently near to that of the metallic element.

(2) By covering the columns or embedding them in Portland cement or in concrete, inside a fireguard of terra-cotta, it is found that the danger from fire contact is satisfactorily obviated,

and atmospheric moisture cannot condense on the metallic surface, and oxidation is prevented besides, providing

(3) The physical proportions that correlate to the desired extent with the artistic sense born of Greek architectural proportions, in which stone or marble constitute the elements of support and strength.

### THE ÆSTHETIC QUESTION.

It has been shown that the artistic objection to the slender cast or steel columns disappears once they are fire-guarded with refractory materials. There is a deeper objection to the proportions of the lofty steel-frame construction *en bloc*. The sense of proportion, which is, of course, the product of one's environment, is offended by the buildings in which the height is so much greater than the width or breadth, but it is remarkable how soon the sense of proportion becomes broadened in contact with the finest examples of the steel-framed structures, and the British architect, Mr. M'Alister, is not alone in his admission that his dislike at a distance of the width of the Atlantic was transformed into delight and fascination in close intimacy with the lofty structural giants of Manhattan Island.

Another British architect, Professor Beresford Pite, has quite recently made a striking architectural proposal, in which he employs the steel-frame system in the rebuilding of St. Bartholomew's Hospital, which, it is suggested, shall have a height of 370 feet above the street curb.

### RAPIDITY OF CONSTRUCTION.

Any one, who is acquainted with the methods in use in Europe, knows that the construction of a building of any importance involves the disfigurement of the street by external scaffolding, and the disorganisation of a business, if the work is one of reconstruction, for periods of one or two years, if not more. The new steel-framed system of construction enables the storey of a building to be erected in one week, which would involve at least a month's time if constructed in the ordinary way, and this fourfold rapidity of construction is performed with the least possible discomfort to neighbouring residents or to street traffic ;

moreover, the superior erecting speed has its recompense in the early rent-earning capacity of the building.

In the ordinary system, in which the masonry walls carry the floors, or part of them, only one set of masons or bricklayers can be employed, but in the steel-frame system, in which each steel-framed floor and its columns carries its outside and partition walls, two sets of masons can be engaged in building these walls on different floors concurrently.

#### GUARDING AGAINST THE EFFECT OF STEEL AND IRON FLAME CONTACT.

The two main requirements that the steel-frame structural system must fulfil, in addition to its adequate support of the floors, walls, and roof, are a satisfactory resistance to the effect of flame contact, and ability to meet the effect of violent wind strains or forces.

The term "fire-proofing" is still applied to some of the modern steel-frame structures, but it is a misnomer, because no system of construction can be said to be actually fireproof—the author could easily, and has, secured flame temperatures that melted silica bricks like water, but such temperatures could not occur under ordinary fire conditions, and to members of the Iron and Steel Institute the statement that it is possible to secure a steel frame refractory guarded type of construction that will resist the effects of ordinary fires without collapsing, even when the stored contents of such buildings are being utterly destroyed by such fire, will be accepted as correct. That the best modern types of steel-framed construction will secure all that can be reasonably demanded as a fire-resisting qualification, is demonstrated by the evidence culled from the reports of the disastrous fires at Baltimore, Rochester, and elsewhere. Out of these terrible conflagrations one fact has risen, Phoenix-like, from the ashes of these disasters, *e.g.* that if steel-frame lofty structures are built in accordance with the best practice, they are almost as resisting to internal fire-effects as is a blast-furnace.\*

\* The prejudice in Europe and Great Britain against the lofty steel-frame construction is only too evident from the character of the references in the public press; one would assume from the published cabled reports concerning the recent great fires at Baltimore and Rochester, U.S.A., that they are almost responsible for the extent of the disasters in the two cities, and that the system from a fire-resisting point of view is a failure.

One building in Chicago had stored in it no less than 80,000 feet of oak lumber; the materials caught fire and were entirely destroyed, but both the steel frame and tiled arches emerged from the fiery ordeal practically uninjured.

The granite steel-frame building at Rochester, according to Mayor Cutler, resisted the fire-effects of the recent conflagration remarkably well. With the exception of a small portion of the east wall, all the rest of the walls are in almost as good condition as before the fire, and 25 per cent. depreciation would amply compensate for the loss. The granite steel-frame building was in the centre of the recent fire zone, and was surrounded by veritable tinder-boxes of buildings, for which it acted like a chimney, the building being subject to an environment of flames for no less than thirty-six hours. It was found after the fire that the terra-cotta fireguards round the cast-iron columns were still intact; the terra-cotta material established its position as the *ne plus ultra* material for guarding iron and steel from flame damage.\*

Mr. Parsons (an American engineer) has reported on the recent terrible disaster at Baltimore. He reports that all the modern well-designed steel-frame buildings, in which the steel was properly fireguarded, had come out of the conflagration practically unscathed and intact. There were a number of lofty steel-frame structures from twelve to eighteen storeys in height within the fire zone; everything combustible within them was utterly destroyed, but the buildings still remained unburned, or, as he reported, practically unscathed and untouched.

All the buildings having non-fireguarded iron beams and columns were destroyed, the remains being a chaotic mass of bricks, twisted, warped and broken iron.

Experience shows that hard-burnt fireclay and porous terra-cotta floor-arches and column and beam fireguards are by far the best.

Evidence from the Baltimore fire of the satisfactory fire-

\* One lesson to be learnt from the Rochester disaster is that the elevator- or lift-wells should be enclosed in brick or terra-cotta walls; no open ironwork should be permitted.

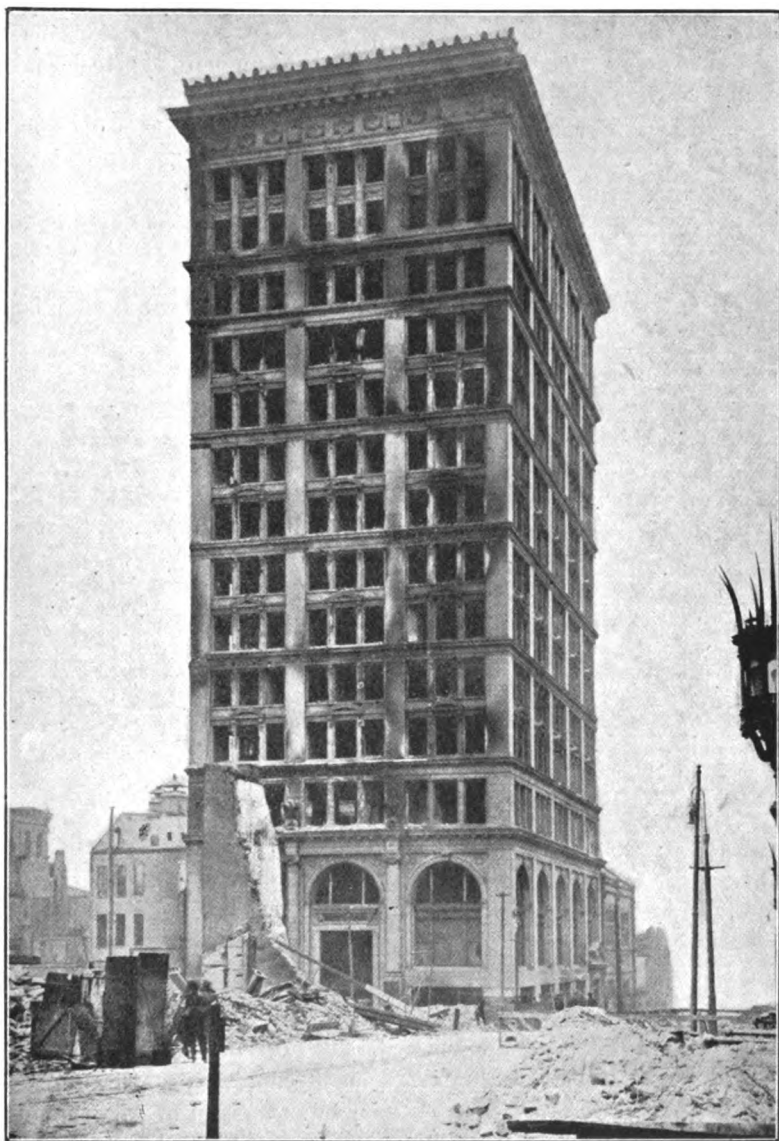


FIG. 10.—The Continental Trust Building, Baltimore Fire, 1904. This steel and tile fireproof structure stands intact after the fire—proof of fire resistance.

resisting character of the steel-frame structures is provided by Figs. 10 and 11.

Evidence of the danger of relying on unguarded steel and iron is provided by Fig. 12.

In fireguarding construction there is, of course, a considerable augmentation of the weight to be carried by floors and columns by the fireguarding arrangements.

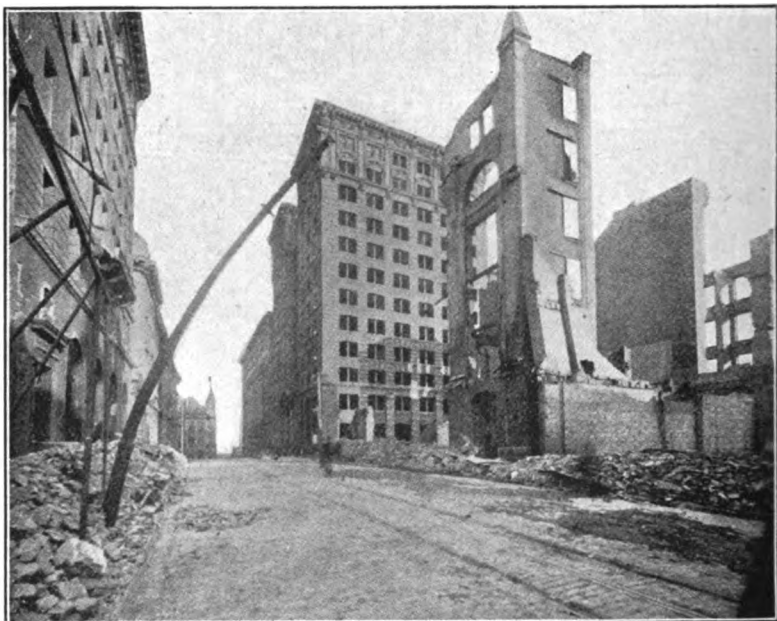


FIG. 11.—Calvert Building, beyond the ruins on the right. Baltimore Fire, 1904. A steel and tile building of fireproof construction. All structural members are absolutely intact. This building received, in some of its upper storeys, the maximum of heat noted anywhere about the burned district.

Mr. Eiffel has long ago claimed that Portland cement covered iron does not rust, and properly made concrete is also an excellent preservative against corrosion, but the steel or iron should be unpainted and thoroughly cleaned from scales and rust.

Steel joists have been removed from buildings after doing service for many years, but having been guarded with Port-

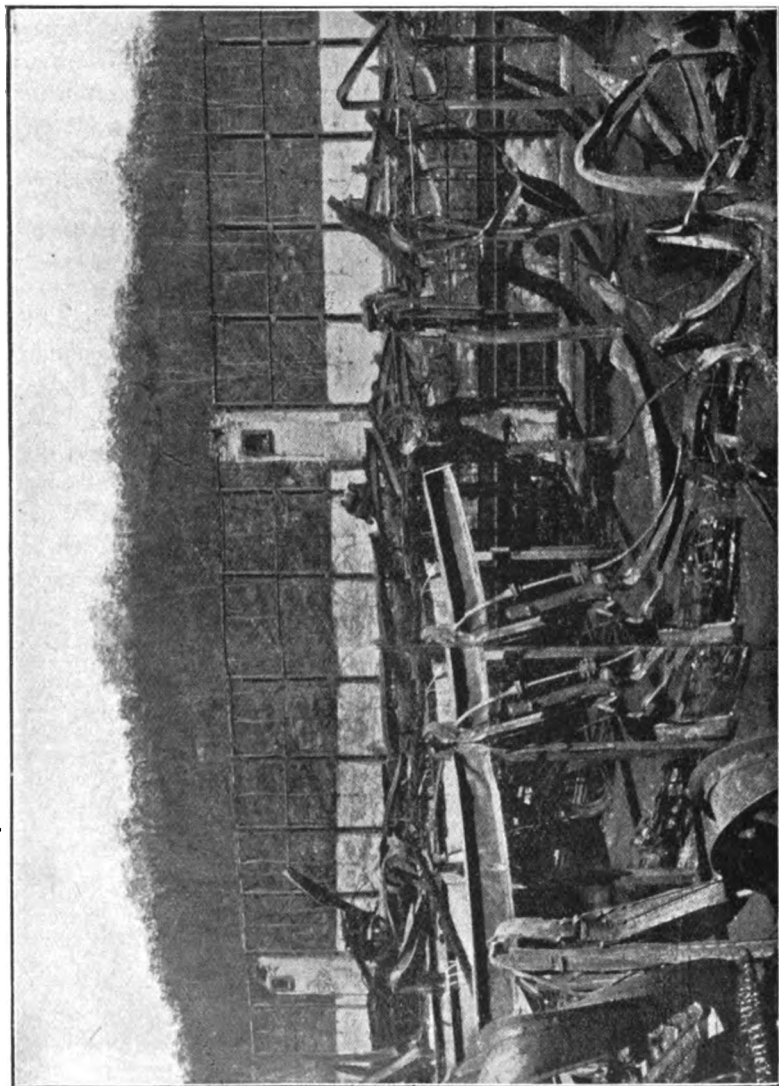


FIG. 12.—The effect of fire on unprotected built-up columns and beams.



land cement their deterioration was an entirely negligible quantity.\*

The author trusts that his paper will inspire an appreciation of a system of construction that relies for its success upon structural steel and iron, and which, if adopted in this country and in Europe in any way like the measure of its adoption in the United States, cannot fail to benefit every branch of the iron and steel industry.

The author has pleasure in thanking the following gentlemen and firms for useful information bearing upon the subject of his paper:—

Col. W. L. B. Jenney (Chicago); Col. Millard Hunsiker of the Carnegie Steel Co., Pittsburg; Mr. Frank W. Skinner (New York), Associate Editor of *Engineering Record*; Judge McConnel of the Fuller Construction Co.; Mr. R. P. Bolton, C.E. (New York); Mr. C. T. Purdy, C.E. (New York); Passaic Steel Co. (Patterson, N.J.); Mr. George H. Blakeley, C.E. (Patterson); Mr. Hunt, Sec., Am. Soc., C.E. (New York); Mr. H. J. Skelton (London); the Illinois Terra Cotta Lumber Company (Chicago); and Mr. William Clendenin (Chicago), Editor of *Fireproof Magazine*.

\* The author was brought into communication some twenty-six years ago with the then official architect of the Cathedral of St. Mark, Venice, in reference to the threatened collapse of the famous mosaic portion of the façade of this beautiful building. On examination it was found that the mosaic work was anchored to the backing of masonry by iron tie-bolts; these by the effects of oxidation had become enlarged, and had fractured the masonry backing, thus endangering the mosaic façade. Probably, then, tie-bolts were the only elements of iron in the entire structure.

ABSTRACT OF PAPER ON THE RELATIONS BETWEEN  
THE EFFECTS OF STRESSES SLOWLY APPLIED  
AND OF STRESSES SUDDENLY APPLIED IN THE  
CASE OF IRON AND STEEL.

BY PIERRE BREUIL (PARIS), CARNEGIE RESEARCH SCHOLAR.

THE author is indebted to the generosity of many of the leaders of the iron industry in France for assistance in carrying out his very numerous tests. He has nevertheless been able to realise only one portion of his programme, and all tests were made at the Laboratory of the Conservatoire National des Arts et Métiers.

The slowly applied, as well as the suddenly applied stresses, whose effect was to be compared, took the form of tensile and bending stresses which were exerted upon ordinary bars, and upon bars which had been specially prepared by notching. It was on account of the widely extended practice in France of making tests on nicked bars that the author decided to try and trace the connection between the deformations occurring in these latter and those which occur in ordinary plain bars, and to endeavour to establish the law which governs them.

It seemed to the author that all investigations hitherto made with this object have failed to take sufficient account of the difficulty in which the users find themselves placed, owing to the fact that these new methods of testing have aroused some feeling of distrust of the old methods. He has therefore attempted to establish the transition stage between the two systems, having been instigated by the anomalies with which he has frequently been confronted in carrying out tests on nicked bars.

The material employed was supplied in the form of square bars, the sides of which measured 18 millimetres. These consisted (1) of acid open-hearth steel specimens containing 0·7, 0·45, 0·38, 0·125, 0·12, and 0·10 per cent. of carbon respectively; (2) of three qualities of steel manufactured in the electric furnace, containing 0·310, 0·515, and 0·600 per cent. of carbon respectively; and (3) of wrought iron of various quality. These materials were also subjected to thermal treatment, which modified their mechanical properties, the three first steels being

annealed, the three next quenched and not tempered, while the remainder, including the wrought iron, were not subjected to any previous treatment. The micro-structure of the steels is shown in plates accompanying the paper.

The machines for the slow tensile and bending tests differed in no respect from those usually employed. They were each provided with an indicator which enabled diagrams to be traced, co-ordinating the stresses with the deformations in the case of all the bars.

The author explains that the object of the idea of notching the bars, which was in order to limit their deformation and show the toughness of the metal by fracturing it across the grain without deforming it if possible, has never been perfectly realised. The various kinds of notching proposed hitherto may, without even testing, be considered open to criticism, for it is immediately apparent that the metal may undergo deformation in spite of every precaution. The notches experimentally tried by the author were made with the saw, with a milling machine, with a drill, and with a lathe, and the difficulties attending the cutting of them are pointed out.

*Slow Tensile Tests.*—For these the notches were made with the saw and with a milling tool on either side of the tensile test specimens, and the depth varied by 1 millimetre from one bar to the next, the total range being from 17 millimetres down to 5. The notches made with the lathe were left with sharp furrows at the bottom, when the depth was from 17 to 14 millimetres. The diameter of the holes made with the drill was increased a millimetre at a time from 2 to 12 millimetres.

The diagrams of the tensile tests permit the following conclusions to be drawn, the elongation being measured in a uniform length of 80 millimetres:

1. As long as the section of the notch is not small, the total apparent limit of elasticity indicated by the curves remains the same, whatever the form of the notches. This limit is the same as that of the bars without notches (with certain exceptions which the author explains).
2. The diagrams of tensile strength are all similar but they diminish in height as the notch is deepened.
3. The maximum load of the notched bars referred to the

unit of the initial notched section is increased (this accords with the results obtained by other experimenters), but the harder the metal the less is the increase. If this maximum load is referred to the unit of notched section at the moment when this section begins to yield, the value is found to be lower than that of the actual breaking load per square millimetre of the smooth bar. These two values approximate to each other more nearly the greater the depth of the notch.

4. In the case of ductile metal the unit load is higher the sharper the V of the notch. The opposite is the case with the hard steels, which often break from bending. By drilling the notches the unit breaking load may be made to agree more nearly with that of the plain bars.

5. The contraction in the notch diminishes with the acuteness of the V of the latter, but it varies little for the same type of notch.

6. The elongation measured upon the curves before they attain their maximum point of elevation includes that which occurs in the notched section and that which occurs in the smooth part of the bar. The elongation occurring after the maximum point of the curve is reached corresponds to the tear in the notch. This tear, which takes place suddenly in the case of hard steels, is relatively slow in mild steel and proceeds in much the same manner, whatever the depth of the notch.

7. The maximum point in the curve of the notched bars occurs at the exact moment when the notch begins to crack, and has no analogy with that of the smooth bars except in the ultimate yield point.

8. The amount of work expended in producing the rupture of notched bars is influenced by the two factors contributing to it (the stresses and the elongations), and it consequently varies greatly, according as the type of notch varies.

Summing up, it would appear from these tests to be necessary, in order to arrive at a uniform qualification of all metals from the point of view of tests with nicked specimens, to make the notch in such a manner that the ultimate load in bending should always be less than the limit of elasticity in the smooth portion of the bars. This would involve varying the notch with each kind of metal; for instance, in the case of mild steel, the bars should be

nicked to a depth equal to half the initial section, and in that of hard steel, to a depth equivalent to one-third only. If this condition is fulfilled, it may be assumed that the results of the tests upon nicked bars are, in reality, of the same order as those of tests upon plain bars, but much less clear and precise. Under these circumstances, why should the bars be nicked at all?

By experimenting with a series of polished bars the author was enabled, by observing the lines representing the distribution of the deformations described by Hartmann, to note that in the nicked bars the deformations began at the point of minimum section under a unit load exactly equivalent to the unit limit of elasticity of the smooth part of the bar. The raising of this limit was only apparent, as one might have been led to expect from the diagrams. The deformation in the neighbourhood of the notch is localised in those parts of the bar, the volume of which varies with the notch, which parts, however, are deformed in the same manner if the notch is of the same type. The volume affected by the deformation varies approximately as the square of the distance between the bottom of the two notches when they are cut with a saw or with a milling tool.

In general the fractures of the notched tensile specimens follow the lines of Hartmann, the surfaces at the point of rupture being fibrous or granular, which seems to indicate irregularity in the distribution of the stresses in the metal. The mild steels are the most characteristic in this respect, while the hard steels almost always show a granular fracture, photographs of which are appended to the paper.

*Slow Bending Tests.*—The notches were made with a saw and a milling tool on one side only of the bars, and they were bent on two supports, a distance apart in one instance of 80 millimetres, in the other of 100 millimetres, and the notches varied in depth from 1 to 7 millimetres. For purposes of comparison planed bars of the same metal, having a thickness equal to the nicked bars at the bottom of the notch, were also bent. The results of the test are graphically represented in a large series of diagrams, and may be briefly summarised as follows:—

1. All the bending curves for one kind of metal were similar, and as in the case of the tensile tests, the curves for the notched bars are fractions of the curves for smooth bars of the same

thickness. A V-shaped notch with a milling tool arrests the curve more quickly than one cut with the saw, but the characteristic outline of the curves remains the same.

2. The curves of the smooth bars show that the limit of elasticity is in accordance with the laws of the resistance of materials.

3. The curves of notched bars reach a maximum at the moment when the first crack manifests itself at the bottom of the notch, but the latter is not completely cracked up to the edges until somewhat later. This point is generally marked by a sudden fall of the curve. The phenomena are particularly clearly marked in the case of mild steel, while with the hard metals rupture takes place at the moment the notch begins to open out. Strictly speaking, mild steels do not break at all even when very deeply notched, so that to classify them exactly is a difficult question.

4. The slightest deviation of the knife edge of the bending press outside the plane of the notch modifies the appearance of the first cracks, and may lead to results which are by no means an indication of the quality of the metal.

5. A very considerable amount of friction occurs between the bars and their supports, which modifies the form of the curves and influences the result of the tests.

6. The contraction of the notched bars diminishes as the notch is enlarged, but only slightly.

7. The work necessary for producing rupture is not without significance, but only in so far as it is applied at the point of notching. Up to the maximum of the curves, however, the work includes that expended in bending the portions of the bar outside of the notched section.

8. The only work which need be taken account of in determining the value of the metal from the point of view of tests with notched specimens is that which is expended after the curves have attained their maximum. But since rupture does not occur in the mild steels it is difficult to obtain an exact criterion.

9. In order to confine the deformation entirely to the notch, care should be exercised to cut less deeply, the harder the metal under investigation, owing to which necessity, however, complications are apt to ensue.

The conclusions to which the author has been led by the study of Hartmann's lines are analogous to those drawn by him from the results of the tensile tests.

The fractures of the bent bars, whether smooth or notched, resemble very much those of the tensile test specimens.

Compared with mild steel, the wrought iron shows a certain superiority in the bending tests with notched bars. The crack successively meets with the laminations which themselves crack and cause the bar to behave much in the same manner as a number of plain bars superposed. The number of bendings and the work expended in the case of the iron are consequently greater than in the case of mild steel.

*Impact Bending Tests.*—All the impact tests made by the author were carried out with a drop-hammer of 10 kilogrammes weight. The factors specially investigated were the height of fall and the depth of the notches. The work expended in producing the flexure both of the plain bars and of the notched bars was measured exactly by determining the amount of work in excess. The distance apart of the supports was uniformly 100 millimetres, and by dint of taking a few precautions the tests gave excellent results. After each successive blow of the drop-weight the bars were laid on a sheet of paper, and the set due to the blow was measured. The results of the tests on the plain bars showed that for an *apparently* equivalent amount of work the set *apparently* diminished when the height of the fall of the drop-hammer was reduced. But on calculating the amount of work expended on the bars and their supports it was found that the same amount of set was produced by the same expenditure of work. This law is general; and, besides, the work performed in dealing the blows is just about equal to the work expended in the slow bending tests. The results with the nicked bars therefore lead the author to the conclusion that it is inadvisable summarily to reject the slow bending tests, which have long been established and give more exact results than sudden bending tests.

*Conclusion.*—The conclusion to which the author ultimately arrives is that the nicking of test bars simply implies the introduction of an additional complication, and he questions whether the numerous discussions which have taken place upon this subject can be justified, in view of the fact that the

ordinary tensile and bending tests when properly interpreted yield results much less open to criticism than those with nicked bars.

The paper, of which this is an abstract, is published in full as a supplement to this volume.



## THE INFLUENCE OF VARYING CASTING TEMPERATURE ON THE PROPERTIES OF STEEL AND IRON CASTINGS.

By PERCY LONGMUIR (SHEFFIELD), CARNEGIE RESEARCH SCHOLAR.

## INTRODUCTORY.

THE occasionally erratic behaviour of castings of known composition and suitable treatment is familiar. Steel castings of identical composition and annealed under similar conditions show at times a wide variation in their mechanical properties. Further, with equal properties, as shown by the tensile test, steel castings may under certain conditions vary in their resistance to working stresses, and in extreme cases fracture may occur at comparatively low stresses. Another source of variation lies in the resistance offered by steel or iron castings to the percolation of water under pressure, and not infrequently this may be met with in similar castings poured from the same ladle.

The present state of foundry practice is such that all conditions, save one, may by the exercise of suitable care be held in good control. That one condition is the temperature of the metal as it enters the mould, and to it the following work has been devoted.

Generally the methods outlined in a former paper have been followed, and every experiment represents identical conditions other than casting temperature. All conditions being strictly comparative, it follows that the results obtained, whether in the cast, annealed, or heat treated condition represent actually the influence of varying casting temperature.

The work has been conducted in the Metallurgical Department of University College, Sheffield, and the many facilities possessed by the college have been freely placed at the author's disposal. Professor Arnold has shown a keen interest in the progress of the work, and the author is indebted to him for many valuable suggestions and much kindly counsel.

## SECTION I.

## CAST AND MALLEABLE CAST IRON.

Preliminary experiments with various types of cast iron conclusively proved the susceptibility of this metal to the influence of casting temperature. Commencing with an extremely hot metal, the tenacity of the cold bars gradually rises as the temperature falls until the "fair" heat is reached, a further fall in casting temperature being accompanied by a corresponding decrease in tenacity. Composition in each series remains constant, the varying properties of metal from one crucible or one ladle is in all probability due to the influence of casting temperature on the intercrystalline cohesion. In the case of white iron this influence survives the annealing process as followed for the production of malleable cast iron.

In no experiment undertaken has the influence of varying casting temperature failed to show, and none of the forms of after treatment adopted have brought the metal to a uniform level. Owing to this agreement over a wide range of composition this section has been condensed. Results obtained from a typical white and grey cast iron are embodied in Table I.

It will be noted that numbers 34, 35, and 36, all poured from one crucible, yield tenacities of 10·7, 15·9, and 12·1 tons per square inch respectively. Companion bars, after undergoing a treatment involving decomposition of one of the chief constituents, and a complete rearrangement of the structure, still exhibit a variation forcibly shown in tenacities of 20·6, 29·2, and 26·5 tons per square inch.

The grey iron is also noteworthy. An examination of Nos. 37 to 39 show that a fall in temperature of 50° C. raises the maximum stress 4·4 tons, whilst a further fall of 105° C. lowers it 3·5 tons. The quenching experiments in this case are negative results included only for their general interest. As anticipated, the bars were finely fissured, and apparently some portion of the free carbon had entered into combination with the iron. Nos. 43 and 44 represent a type of unsound composition poured at a "high" and "fair" casting heat, both sets of bars being equally unsound. In spite of this equal unsound-

TABLE I.—Showing the Influence of Varying Casting Temperature on the Properties of Cast Iron.

No.	Analysis.						Casting Temperature.	Condition.	Mechanical Properties.		
	CC.	Gr.	Si.	Mn.	S.	P.			Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 in.
34	3.4	...	0.39	0.05	0.02	0.02	1320° C.	As cast	...	10.7	...
35	"	...	"	"	"	"	1230° C.	"	...	15.9	...
36	"	...	"	"	"	"	1120° C.	"	...	12.1	...
34HT	0.77	2.57 +	"	"	"	"	1320° C.	Heated to 1000° C. and slowly cooled	...	18.6	...
35HT	"	"	"	"	"	"	1230° C.		...	24.0	...
36HT	"	"	"	"	"	"	1120° C.	"	...	21.6	...
34A	0.2 to 0.5*	3.2	"	"	"	"	1320° C.	Annealed 100 hours in ore	20.0	20.6	1.0
35A	"	"	"	"	"	"	1230° C.		24.3	29.2	3.5
36A	"	"	"	"	"	"	1120° C.		22.5	26.5	2.0
37	0.52	3.4	1.78	0.28	0.04	0.27	1400° C.	As cast	...	9.7	...
38	"	"	"	"	"	"	1350° C.	"	...	14.1	...
39	"	"	"	"	"	"	1245° C.	"	...	10.6	...
37HT	Not estimated	"	"	"	"	"	1400° C.	Heated to 940° C. and cooled in air	...	7.1	...
38HT	"	"	"	"	"	"	1350° C.		...	9.9	...
39HT	"	"	"	"	"	"	1245° C.	"	...	8.5	...
37A	Not estimated	"	"	"	"	"	1400° C.	Annealed for 48 hours in a Clinch Jones muffle	...	6.5	...
38A	"	"	"	"	"	"	1350° C.		...	7.2	...
39A	"	"	"	"	"	"	1245° C.		...	2.6 +	...
37Q	Not estimated	"	"	"	"	"	1400° C.	Heated to 940° C. and quenched in water	...	2.5	...
38Q	"	"	"	"	"	"	1350° C.		...	3.0	...
39Q	"	"	"	"	"	"	1245° C.		...	2.7	...
43	3.35	...	0.03	0.03	0.02	0.02	1440° C.	As cast	...	9.4	...
44	"	...	"	"	"	"	1299° C.	"	...	12.1	...
43HT	Not estimated	"	"	"	"	"	1440° C.	Heated to 1000° C. and cooled in air	...	13.3	...
44HT	"	"	"	"	"	"	1299° C.		...	17.2	...
43A	Not estimated	"	"	"	"	"	1440° C.	Heated to 1000° C. and cooled in muffle	...	18.8	...
44A	"	"	"	"	"	"	1299° C.		...	20.5	...

\* Values according to proximity of drillings to outside or centre of bars, from 0 to 0.2 and 0.5.  
 + Results obtained from average drillings.

ness the tenacities show a difference of 2·7 tons per square inch in favour of the fair heat, and a distance apart is still maintained on subsequent treatment.

These results, confirmed by the preliminary work, sufficiently show the importance of casting temperature in the case of cast iron. The chief object of this research is, however, to show its direct bearing on foundry practice, and it was desired to ascertain if this influence holds good in all cases, irrespective of (1) composition, or (2) size of the castings. Work is now progressing in this direction; and the first series of results are embodied in Table II. These bars, 16 inches long by 0·5 inches diameter, were selected in order to determine if the relatively rapid solidification minimised the effect of varying casting temperature. The plan followed was to secure three sets of three bars each at three distinct temperatures from one crucible. One bar of each set was tested as cast, and the remaining two after treatment. The influence of casting temperature is well shown, but on the whole the results are low, owing to the small diameter and long length of the bar under test.

## SECTION II.

### STEEL CASTINGS.

As in the cast-iron section, only sound bars are here considered, and casting temperature is for the present studied solely in its relationship to the mechanical properties. At the outset, it is well to state that mild steels are not readily overheated in the crucible furnace, and no telling example of excessive casting temperature has been obtained from mild crucible steel. Good examples of "scalded" tool steel have been obtained, and with mild castings the low temperatures have yielded important results.

Recognising the difficulty of producing typical high casting temperatures, Messrs. D. Rennie & Co., Camlachie Steel Foundry, Glasgow, kindly placed a 2-ton Robert converter at the service of this research. Mr. D. Rennie, jun., and Mr. G. Rennie entered heartily into the matter, furnishing the author with unlimited material of known casting conditions. Special blows

TABLE II.—*Showing the Influence of Varying Casting Temperature on the Properties of small Iron Castings.\***Test Bars, 0.5 in. diameter × 16 in. long. Length of piece under test, 9 in.*

No.	Analysis.						As Cast.	Heated for Three Periods of 7 hours at 1000° C.	Heated to 1000° and slowly cooled.
	CC.	Gr.	Si.	Mn.	S.	P.	Maximum Stress. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Maximum Stress. Tons per sq. in.
A 50	3.4	...	0.04	0.03	0.03	0.02	6.5	5.0	4.9
51	"	...	"	"	"	"	8.0	7.3	10.0
52	"	...	"	"	"	"	6.2	6.9	7.5
B 53	3.4	0.06	0.11	0.10	0.02	0.02	5.3	8.6	7.3
54	"	"	"	"	"	"	9.1	13.5	13.0
55	"	"	"	"	"	"	8.4	10.0	8.9
C 56	3.3	0.21	0.35	0.18	0.04	0.013	4.0	7.5	8.4
57	"	"	"	"	"	"	8.9	10.6	14.0
58	"	"	"	"	"	"	6.4	8.3	9.0
D 59	3.0	0.35	0.45	0.17	0.04	0.017	5.0	Not tested.†	11.3
60	"	"	"	"	"	"	8.3	10.0	14.1
61	"	"	"	"	"	"	7.1	9.3	11.2
E 62	...	...	0.61	0.08	0.02	0.012	5.6	7.0	8.9
63	...	...	"	"	"	"	9.0	9.8	13.6
64	...	...	"	"	"	"	6.7	6.5	11.0
F 65	...	...	0.80	0.09	0.02	0.014	6.5	7.9	9.4
66	...	...	"	"	"	"	8.0	10.0	14.5
67	...	...	"	"	"	"	6.1	9.2	10.3
G 68	...	...	1.12	0.08	0.03	0.015	7.6	Not tested.†	8.6
69	...	...	"	"	"	"	11.0	"	13.2
70	...	...	"	"	"	"	6.7	"	8.3
H 71	...	...	1.47	0.30	0.03	0.011	7.0	7.6	7.0
72	...	...	"	"	"	"	10.0	11.1	12.8
73	...	...	"	"	"	"	8.8	9.0	8.3
I 74	...	...	2.1	0.40	0.05	0.02	5.8	4.0	5.5
75	...	...	"	"	"	"	12.0	8.0	12.0
76	...	...	"	"	"	"	5.5	6.2	5.8
J 77	...	...	2.7	0.30	0.04	0.02	5.3	Not tested.†	7.4
78	...	...	"	"	"	"	10.4	"	12.1
79	...	...	"	"	"	"	7.5	"	9.0

\* The small diameter of these castings, and the relatively rapid solidification, prevent them showing the effect of an increasing content of silicon. A similar series of bars 1 inch diameter is contemplated.

† Seven of these bars were too warped to test.

have been conducted, and several series of castings representing various casting temperatures obtained. All other conditions are equal, and each series of annealed bars received exactly the same treatment. Careful analytical examination has, as yet, detected no change in composition, in any one series, due to variation in casting temperature.

The author would here tender Messrs. Rennie his most cordial thanks for their interest in the matter, for their favour in supplying several series of bars, and, above all, for independently confirming many of the results.

The results embodied in Table III. show clearly the influence of varying casting temperature on steels that have been initially overheated. It will be noted that one of the series of this table is abnormally high in sulphur. This experiment was specially conducted to ascertain the influence of varying casting temperature on the properties of a mild steel comparatively low in manganese and fairly high in sulphur. An examination of Nos. 90, 91, 92, and 93 is not without interest, the influence of casting temperature is distinctly shown on the tenacities both in the cast and annealed condition. The bending angles of the annealed bars were  $75^{\circ}$ ,  $120^{\circ}$ ,  $80^{\circ}$ , and  $70^{\circ}$  respectively, and from steels of low extensibility these bending angles are comparatively high.

The remaining steels of Table III. are normal as far as composition is concerned, and attention is drawn to the elongations and contraction of areas. As these results show, the influence of casting temperature is not removed by annealing. The fact that extensions starting from 9.5, rising to 24.0, and falling to 8.0 per cent. may be obtained from one cast with metal in precisely the same condition other than casting temperature is of high practical importance. Nos. 84 to 86 cast at selected temperatures from one cast, and annealed together, confirm Nos. 80 to 83. With a harder steel poured at selected temperatures from the fair heat downwards, the extensibility falls from 22.5 to 6.5 per cent. The results obtained from Nos. 90 to 93 illustrate not only the survival of casting temperature, but also show a type of steel not amenable to subsequent treatment.

The difficulty of obtaining typical "high" casting tem-

TABLE III.—The Influence of Varying Casting Temperature on the Properties of Steel Castings of Identical Composition, poured from one Heat.

No.	Analysis.				Condition.	Mechanical Properties.			Remarks.
	CC.	Si.	Mn.	S.	P.	Elastic Limit. Tons per sq. in.	Maximum stress. Tons per sq. in.	Elongation per cent. on 2 in.	
80	0.29	0.07	0.15	0.07	0.06	13.5	20.3	5.0	Poured in rotation at intervals from "high" to "low" during one cast.
81	"	"	"	"	"	14.3	24.2	9.0	
82	"	"	"	"	"	13.6	26.0	10.0	
83	"	"	"	"	"	12.8	23.0	8.5	80 to 83 annealed.
80A	"	"	"	"	"	12.5	24.2	9.5	
81A	"	"	"	"	"	13.5	27.2	24.0	
82A	"	"	"	"	"	13.3	27.0	12.5	
83A	"	"	"	"	"	13.2	25.5	8.0	Representing three typical casting temperatures from one cast.
84A	0.28	0.15	0.29	0.06	0.05	10.2	30.9	15.5	
85A	"	"	"	"	"	15.4	28.0	33.5	
86A	"	"	"	"	"	16.4	30.3	27.5	
87A	0.51	0.11	0.42	0.06	0.05	18.0	33.4	22.5	Fair to low casting temperature from one cast.
88A	"	"	"	"	"	17.0	36.7	20.0	
89A	"	"	"	"	"	15.7	36.2	6.5	
90	0.20	0.04	0.38	0.15	0.06	11.7	14.2	3.5	Example of the influence of varying casting temperature on a mild steel fairly high in sulphur.
91	"	"	"	"	"	14.8	21.5	5.0	
92	"	"	"	"	"	13.8	21.4	5.0	
93	"	"	"	"	"	12.6	17.5	3.5	
90A	"	"	"	"	"	11.4	15.8	6.5	90 to 93 annealed.
91A	"	"	"	"	"	13.0	22.1	7.5	
92A	"	"	"	"	"	12.5	21.8	10.0	
93A	"	"	"	"	"	12.2	20.8	10.0	
90HT	"	"	"	"	"	13.5	15.5	5.0	90A, 91A, 92A, and 93A heated to 1000° C., and slowly cooled.
91HT	"	"	"	"	"	14.2	16.7	8.0	
92HT	"	"	"	"	"	14.9	22.9	11.0	
93HT	"	"	"	"	"	14.1	20.7	10.0	

peratures from mild crucible steels has been referred to; practically there is no danger of such metal being poured at too high a temperature.\* There is, however, a strong possibility of the steel being cast too cold. A peculiar feature of mild crucible steels poured at "fair" and "cold" heats lies in the fact that generally their tensile properties are very similar if not identical; the actual properties of these steels are, however, anything but similar, and from one crucible two castings may be obtained, one of which may be dangerously brittle.

Table IV. embodies some of the tensile results obtained from crucible steels. From the first three steels a steady fall in tenacity with a falling temperature is perceptible. Nos. 97 to 100 embrace two steels of nearly uniform composition in three conditions, viz., cast, annealed, and forged, each condition including two distinct casting temperatures. This series is intended as a comparison of casting temperature on castings and forgings. Nos. 99 to 100 represent two ingots poured at the "fair" and "cold" heats respectively; they were cogged down to 1 inch round bars under identical conditions—in other words, reheated to the same temperature and both finished at the same heat.

The tensile results obtained from these steels as cast and forged are worthy of attention, and it will be noted that here the influence of casting temperature is not shown.† No. 98A in bending reached an angle of  $160^{\circ}$ , and then broke "short." The two ends of 97A were brought together without sign of flaw, both 99 and 100 being similarly treated. Yet in breaking pieces of 98A by means of a hammer decisive brittleness was shown and approximately these pieces required only one half the energy necessary to fracture similar pieces of 97A. This type of brittleness appears to be induced by a low casting temperature, and provided the steel has not been overheated, is not, as a rule, evidenced in the results obtained from a tensile test.

Professor Arnold has shown the existence of two distinct types of brittleness:‡ (1) mechanical brittleness, and (2) vibratory brittleness. The first is apparent, whilst the second type is met with in steels of good tensile properties, but which under

\* This statement applies only to mild castings, and does not include tool steels.

† When melting, the "fair" heat was not exceeded in either case.

‡ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cliv., supplement.



TABLE IV.—The Influence of Varying Casting Temperature on the Properties of Steel Castings.

No.	Casting Temperature.	Analysis.				Con- dition.	Mechanical Properties.				Bending Angle.	Remarks.
		CC.	Si.	Mn.	S.	P.	Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.		
94	1500° C.	0.47	0.22	1.04	0.05	0.016	24.0	38.6	4.5	6.0	30° broken	Three 50-lb. crucibles charged together but drawn at different temperatures.
95	1481° C.	0.50	0.20	0.96	0.05	0.017	24.6	36.4	3.0	5.4	23° "	
96	1431° C.	0.47	0.20	1.00	0.05	0.016	18.5	31.0	2.5	3.8	10° "	
94A	1500° C.	0.47	0.22	1.04	0.05	0.016	18.0	37.1	13.0	15.2	80° broken	Nos. 94, 95, and 96 annealed.
95A	1481° C.	0.50	0.20	0.96	0.05	0.017	18.4	36.4	7.5	9.2	60° "	
96A	1431° C.	0.47	0.20	1.00	0.05	0.016	16.8	22.5	3.0	8.1	33° "	
97	1550° to 1600° C.	0.36	0.22	0.89	0.02	0.02	18.4	35.8	12.5	12.5	75° broken	From one crucible. 98 poured 2 min. later than 97.
98	1470° to 1500° C.	"	"	"	"	"	18.0	34.2	11.5	17.4	80° "	
97A	1550° to 1600° C.	"	"	"	"	"	14.2	27.0	17.5	17.4	180° unbroken	97 and 98 annealed.
98A	1470° to 1500° C.	"	"	"	"	"	16.0	28.2	18.5	18.0	160° broken	
99	1550° to 1600° C.	0.37	0.18	0.87	0.03	0.02	25.6	40.9	27.5	54.0	180° unbroken	From one crucible. 100 cast 2 min. later than 99.
100	1470° to 1500° C.	"	"	"	"	"	24.5	40.1	28.0	50.0	180° "	
101	1611° C.	0.29	0.14	0.92	0.06	0.02	18.5	30.9	7.5	13.1	...	From one crucible. 1½ min. interval.
102	1560° C.	"	"	"	"	"	18.5	30.1	7.0	12.1	...	
101A	1611° C.	"	"	"	"	"	16.0	29.1	19.5	18.4	180° unbroken	101 and 102 annealed.
102A	1560° C.	"	"	"	"	"	15.2	28.4	18.5	18.4	106° broken	
103	1653° C.	0.08	0.04	0.06	0.03	0.01	10.3	18.7	15.0	27.4	180° unbroken	From one crucible. 1 minute interval.
104	1613° C.	"	"	"	"	"	"	"	"	"	180° "	
103A	1653° C.	"	"	"	"	"	7.2	18.5	35.0	52.2	180° unbroken	103 to 104 annealed.
104A	1613° C.	"	"	"	"	"	"	"	"	"	180° "	

certain conditions are liable to fracture under alternation of stress at a stress far below their elastic limit. Mr E. G. Izod \* has recently, in a paper read before the British Association, confirmed Professor Arnold's results. Professor Le Chatelier,† in speaking of accidental fractures, has stated their source to be in the intermittent brittleness of the metal, "a brittleness not made apparent in the tensile test, but which is felt under certain conditions, especially when the metal is in use."

Early in the present research the question of brittleness assumed importance, and it was specially desired to ascertain if the second type described by Professor Arnold was a function of casting temperature. The results shown on Table V. are worthy of note, steel No. 97 withstood sixty-eight reversals of stress, whilst No. 98 fractured on forty-eight reversals. Even after annealing 98A is not brought to the same level as 97 in the cast condition. The forged steels are, however, of greater moment, the fair heat, No. 99, requiring 546 reversals to effect fracture, whilst the cold one, No. 100, required only 172. At present any definite statement on these results is hardly possible; there is, however, a strong probability that the cause of many mysterious fractures of steel of high ductility, as shown by the tensile test, may be traced to the original ingot being cast at either too high or too low a temperature.

TABLE V.—*The Influence of Varying Casting Temperature on the Properties of Steel as Evidenced by Alternation of Stress.*

DATA.—270 reversals per minute,  $\frac{1}{8}$ -inch stroke, test-piece  $\frac{3}{8}$  inch  $\times$   $\frac{1}{2}$  inch.

No.	Casting Temperature.	Condition.	Reversals to Complete Fracture.	Max. Stress. Tons Per Square Inch.	Elongation Per Cent. on 2 Inches.
97	1550° to 1600°	As cast	68	35·8	12·5
98	1470° to 1500°	„	48	34·2	11·5
97A	1550° to 1600°	Annealed	122	27·0	17·5
98A	1470° to 1500°	„	62	28·2	18·5
99	1550° to 1600°	Forged	546	40·9	27·5
100	1470° to 1500°	„	172	40·1	28·0

\* *Engineering*, vol. lxxvi., No. 1969, p. 431.

† *The Iron and Steel Metallurgist*, vol. vii., No. 2.

The severity of the foregoing test may be exemplified by the following results. A casting showing a tenacity of 28 tons per square inch and an elongation of 26 per cent. fractured after forty-one reversals. Pure iron as cast and annealed fractured on 72 and 198 reversals respectively. As an extreme illustration, a casting of 38 tons maximum stress and 4 per cent. elongation fractured on four reversals, a similar casting poured at a slightly lower temperature broke on eight reversals. After annealing, these results were raised to 26 and 102 reversals respectively.

*The Influence of Casting Temperature on Specific Gravity.*—Much work has been devoted to this section, and with iron or steel no correlation has at present been established between casting temperature and density. However, as shown in the first part of this research, the appearance of runner heads is often a good index as to whether the casting temperature has been suitable or not. Similarly, the top surface of a steel ingot may also serve as a guide, reference to Fig. 21, Plate IV., shows three mild ingots from one cast, representing three casting temperatures.

## SECTION III.

### MICROSCOPICAL.

On the whole, the nett results of this section are not comparable with the work expended on it. The chief effort was directed to ascertain if the varying mechanical properties of iron or steel poured from one ladle could be satisfactorily explained by the influence of casting temperature on structure. The "fair" casting heat, as a rule, favours a less distinct type of crystallisation than either the "high" or "low" heats. The "low" heats are characterised by a very distinct type of crystallisation, and with medium carbon steels the junctions between the pearlite and ferrite are very sharp. The fact has also been proved that the "loose" structure of the "high," the "inter-locked" structure of the "fair," and the "sharp" one of the "low" casting heats survive an equal heat treatment.

The bulk of the work, however, indicates that the influence of casting temperature is exerted on the crystal junctions, for

with each metal or alloy examined a certain casting temperature (the fair one) favours a distinctly stronger type of internal cohesion.

Thus when sections of pure metal, cast at typical "fair" and "low" heats, are etched under strictly comparative conditions, the crystal junctions of the latter appear before the former, and on termination of the etching the junctions of the "cold" metal are more pronounced, *i.e.* deeper and broader. These conclusions are based on results obtained from zinc, tin, copper, and iron. References to Figs. 1 and 2, Plate I., illustrate this feature, and the difference in the crystal junctions of nearly pure iron, cast at  $1653^{\circ}\text{C}$ . and  $1613^{\circ}\text{C}$ ., is readily apparent. In this and the following cases all etching conditions are strictly comparative; that is, each set of sections etched simultaneously in one dish and for exactly the same time.

In connection with the figures on Plate XX., Professor Arnold described similar features in 1901,\* and the following quotation from his research is included owing to its direct bearing: "On deeply etching the two under exactly the same conditions, FeB presented very large ferrite crystals with close joints, whilst 473 showed small crystals with loose junctions—that is to say, the etching acid developed broader spaces between them."

The influence of casting temperature on the structure is well shown in the case of white cast iron in Figs. 3 to 5, Plate XXI. The noteworthy feature is that these structures, after a complete rearrangement due to the decomposition of the cementite, still show a difference, as illustrated in Figs. 6, 7, and 8, Plate XXII. The high mechanical properties of Fig. 7 are readily explained by its structure, or rather its lack of structure, for the constituents so merge one into the other as to give the characteristic interlocking or interwoven type, whilst Figs. 6 and 8 are distinctly sharp.

Under various forms of etching the grey cast irons presented comparatively little difference, and practically none that could be definitely stated as due to casting temperature. On heat-tinting, the high temperature casting showed a large and irregular cellular structure, the "fair" casting heat presented similar features though on a much smaller scale, none of the cells being

\* *Journal of the Iron and Steel Institute*, 1901, No. I. p. 175.

continuous, whilst the "cold" casting had a distinctly sharp appearance. Figs. 9 and 10, Plate XXIII., reproduce the "high" and "low" grey irons, and there the curious cellular structure referred to will be noted.

On Plate XXIV. the structures of steels 84A to 86A are reproduced. The first of these steels was cast at a temperature probably the highest possible for mild steel. The structure of the annealed steel (Fig. 11) is characterised by the distinctly sharp ferrite junctions, no similar junctions showing in Figs. 12 and 13. The merging of pearlite and ferrite one into the other with no apparent junction, typical of the "fair" casting heat, is well shown in Fig. 12; whilst in Fig. 13 these constituents are showing signs of a sharper separation.

Plate XXV. reproduces the structures of three annealed castings of higher carbon content, commencing with the fair casting heat. The interlocked and broken structure of Fig. 14 gives place, with a falling casting temperature to the sharper structures of Figs. 15 and 16. These steels, poured from one cast at different temperatures, and simultaneously annealed under absolutely identical conditions, form very telling examples of the survival of the influence of casting temperature through prolonged heat treatment.

Finally, Plate XXVI. represents four structures illustrating steels 90 to 93 in the cast condition. These steels were poured at intervals from "high" to "low." Fig. 17 is apparently the best structure of the four, and yet it represents a tenacity of only 14·2 tons per square inch.

#### PRACTICAL CONSIDERATION.

This portion has been already treated in the first part of this research.\* It may be well, however, to state again that a suitable casting temperature for any given alloy is not constant, but varies with the form and weight of the casting. Other determining conditions are the rate of pouring, the form of runner and gate, and the distance travelled by the metal before entering the mould. By taking advantage of these determining conditions, and commencing with a sufficiently high casting temperature,

\* *Journal of the Iron and Steel Institute*, 1903, No. I. p. 457.

matters can be readily arranged so that each mould is poured at the correct heat. In determining this correct heat, experience must, until a very considerable advance has been made in pyrometer methods, be the only guide. Empirical though this may be, when carefully applied regularly successful results follow.

In conclusion, the author would again acknowledge the splendid facilities granted by, and ready advice always available from, Professor Arnold and his colleague, Mr. McWilliam.

The staff of the college have united in forwarding the research. It is impossible to acknowledge each individually, but to Mr. F. K. Knowles the author's most cordial thanks are due. The students of the metallurgical department have rendered valuable assistance in the analytical portion of the work, and the author would specially acknowledge the services in this direction of Messrs. Clarke, Swinden, Moorhouse, Mather, Graham, Williams, and Brooke.

To Mr. D. Rennie, jun., and Mr. G. Rennie, of the Camlachie Steel Foundry, Glasgow, the author's highest thanks are due for providing material and independently confirming results.

The author desires also to acknowledge the accurate manner in which the many test-pieces have been machined by Mr. J. Harrison, test-piece maker to the college.

## CORRESPONDENCE.

Mr. W. H. HATFIELD (Sheffield) wished to point out in reference to the effect of the temperature at which cast iron or malleable cast iron castings are cast upon their tensile strengths, that his experience confirmed Mr. Longmuir's. His results were not so decisive as the author's, but castings cast very hot were certainly inferior to those cast at normal temperatures.

He desired to ask the author how he explained the apparent inconsistency in the following results, abstracted from his tables.

*Table I.*—Metal containing

0·39 per cent. silicon,  
0·05 per cent. manganese,  
0·02 per cent. sulphur,  
0·02 per cent. phosphorus,

was materially affected by being heated to 1000° C. and slowly cooled. The combined carbon per cent. was lowered to 0·77 per cent. and the tensiles raised to 18·6, 24·0, and 21·6 tons respectively.

*Table II.*—Metals containing

0·35 to 0·45 per cent. silicon,  
0·17 to 0·18 per cent. manganese,  
0·04 per cent. sulphur,  
0·013 to 0·017 per cent. phosphorus,

remain almost unaltered chemically after the same thermal treatment; they gave only a maximum tonnage of 14·1, one result being so low as 8·4 tons.

Whilst these results would appear to him inconsistent, he was also surprised that a metal of the composition of the first one quoted should have become so materially affected by its particular heat treatment.

Moreover, in Table I., Mr. Longmuir stated that some of his samples were annealed for 100 hours. Was it not important that the portions of this time given to heating up, maintaining of temperature, and letting down again should be known.

The author on page 430 would give one to understand that he thought there might be a correlation between the appearance of casting heads and ingot tops and the specific gravity of the

metals. As the first was due to the freedom or otherwise from defects in the mass, and the latter was due to the molecular condition of the material, did this not seem unlikely?

Mr. A. McWILLIAM (Sheffield) wrote congratulating the author on the way in which he had carried out his research. The subject of casting temperature had for a long time occupied the minds of many connected with the manufacture of metals, and in a general way it was known that for the best results the proper casting temperature must be used. His own empirical instructions in the works with regard to special crucible steels had been to cast as cold as possible, consistent with the last drop being liquid and falling into a thoroughly liquid bath. While watching some of the author's experiments he felt that those ideas came very near to the author's fair heat, and were a good example of how one may strike correct methods in a purely empirical manner. The author was, however, he thought, the first to show the very clear and persistent maximum in the tests of the metals obtained while casting in a descending series of temperatures, and on that most important discovery, borne in upon him by his own practical experience, and corroborated and made definite in his Carnegie scholar work, he was much to be congratulated, as the point was an important one that ought to be thoroughly appreciated alike by the manufacturer and by the general student of metallurgy. The cause of this now well-established fact was still obscure. The author made one suggestion, and at least one other had been made, but much remained to be cleared before reasonable confidence could be felt in the speculations, and the theory must fit in with this decided maximum at the fair heat with lower results when cast either hotter or colder, together with the strange survival of the relative positions after such revolutionising processes as the malleable iron annealing.

Several press notices had stated that the author says it is almost impossible to overheat mild steel for castings, hence the statement on page 423 might perhaps better read: "Mild steels are not readily overheated in the ordinary coke steel melting crucible furnace," although to the careful reader it is quite clear that Messrs. Rennie's experiments were specially designed to



enable the author to test this very point, and clearly showed that mild steel could be overheated.

Mr. JOHN PARRY (Ebbw Vale) thought the results given coincided closely with the rough experience acquired in everyday work. Quoting from his own practice, he had always paid great attention to the casting temperature, more especially as regards steel. Casting too hot was found in many instances to completely spoil the metal. On the contrary, it was found that by waiting a short time and roughly testing by plunging a bar of iron into the fluid metal, until it slightly adhered to the bar, metal of the same composition as very hot metal gave a superior steel. Beyond this point the metal deteriorated. This also was well known to men in the iron foundry. Of course they had no means of exactly determining the heat most suitable, and sometimes failed, generally from allowing the metal to cool too much. He thought it was correct, in the light of recent researches, to say that the results noted were due to influence of casting temperature on intercrystalline structures.

Mr. LONGMUIR in reply noted with pleasure the agreement in the results obtained by Mr. Parry in works practice. In reply to Mr. Hatfield's remarks, he would in the first place state that the analyses of Table II. referred to the cast material only, no analyses of the heat-treated material being given, hence the apparent inconsistency. The low results of Table II., as stated on page 423, were due to the relatively small diameter and long length of the rods tested. The description, "annealed for 100 hours," on Table I. included the total time; that is, time occupied in heating to and maintaining at the maximum temperature and letting down again.

The definition of a fair casting heat given by Mr. McWilliam was most useful and concise, and if adopted in works practice would eliminate many faults due to unsuitable casting temperature. Too often the last drop of metal contained in crucible or ladle was not liquid.

## *THE ANNUAL DINNER.*

THE Annual Dinner of the Institute was held in the Grand Hall of the Hotel Cecil, on the evening of Friday, May the 6th. The President, Andrew Carnegie, LL.D., presided, and among the noblemen and gentlemen present were the Duke of Argyll, Lord Grey, Lord Glasgow, the Lord Chief Justice, Lord Kelvin, Lord Stanley of Alderley, Lord Hugh Cecil, M.P., Sir Bernhard Samuelson, Bart., Sir Lowthian Bell, Bart., Sir Benjamin Hingley, Bart., Sir Edward Grey, Bart., M.P., Sir J. Brunner, Bart., M.P., Sir E. H. Carbutt, Bart., Sir E. J. Reed, K.C.B., M.P., Sir Norman Lockyer, K.C.B., Sir William White, K.C.B., Sir William Turner, K.C.B., Sir John Jones Jenkins, Sir Walter Foster, M.P., Sir H. Truman Wood, Sir Joseph Leigh, M.P., Sir Joseph Lawrence, M.P., the Hon. Hall Jones (Minister for Public Works, New Zealand), Mr. Seth Low (ex-Mayor of New York), General F. T. Lloyd, C.B., Professor J. W. Judd, C.B., Archdeacon Sinclair, Mr. Fletcher Moulton, K.C., M.P., Mr. W. Abraham, M.P., Mr. W. R. Cremer, M.P., Professor James Dewar, Mr. Passmore Edwards, Mr. Henry Clay Evans, Mr. D. Lloyd-George, M.P., Dr. Hew Morrison, and Mr. Thomas Shaw.

Grace was said by the Venerable W. M. Sinclair, D.D., Archdeacon of London and Canon of St. Paul's.

The PRESIDENT, in proposing the toast of "His Majesty the King," said the name was received everywhere with enthusiasm. His Majesty had been during the year on foreign missions fruitful in the extreme. He was a most important national asset. He (Mr. Carnegie) would ask them all to drink to the health of perhaps the most popular individual in the world that day—His Majesty the King.

The PRESIDENT next proposed "Her Majesty, Queen Alexandra, their Royal Highnesses the Prince and Princess of Wales, and the other members of the Royal Family."

Sir WILLIAM WHITE, in proposing "The Houses of Parliament," said he had some experience on the floor of both Houses. He had seen the House of Commons rise, on occasions of national stress, to the discussion

of questions of the state of the Navy in a manner worthy of its reputation, when all parties joined together, and sinking party distinction they met the needs of the moment without the least hesitation, and when millions have been voted freely at a time when the Government said that those millions had to be spent in the Imperial interest. He had to connect with this toast three great names. As representing the House of Lords he had to give them the name of His Grace the Duke of Argyll, a nobleman who had been tested in many ways and had never failed; who had taken an active part in the work of the House of Commons, and now in the House of Lords intervened but too rarely in debate, because they all knew, from his ability and experience, that he could never enter upon a discussion without adding value to the debate. For the House of Commons he had to mention two names, that of Lord Hugh Cecil, a man who thought for himself and always had the courage to express his opinion and go his own way, and the name of Sir Edward Grey, a name always associated with what made for the advance of the people, for freedom and liberty of thought, and for all that helped for progress; a man who had already distinguished himself in many ways, and of whom their hopes for the future were great. He proposed the toast of "The Houses of Parliament," coupled with the three names mentioned.

THE DUKE OF ARGYLL, having suitably acknowledged the toast on behalf of the House of Lords,

LORD HUGH CECIL rose to reply for the House of Commons. He said a great many people desired that Parliament should do something or other for National Industry. There were all kinds of different proposals, some of them much too controversial to be mentioned, some of them of a very modest character indeed. They ranged from that cooling draught, under which title they might describe the proposal that they should establish a Minister of Commerce, to those tremendous electuaries which a certain commission are believed to be now compounding. As to a Minister of Commerce, he hoped that the industries of our country would not suffer from the misfortune that had beset another branch of national reform. Every one who had studied Army Reform must, he was sure, have observed that a great deal of Army Reform depended upon the richness of our language in synonyms. They had always at hand an abundance of nomenclature, and when the critics of the War Office got more troublesome than usual everybody was given a new name, and that

obviated criticism for some time. Now he hoped that those who were interested in the industries and commerce of the country would not believe that a Minister of Commerce was necessarily a much more competent person than a President of the Board of Trade. He believed that that country won wars which had the best generals, and that that country was most successful in industry and commerce which had the ablest and most skilful manufacturers, and the most industrious and the most thrifty labourers at its command. He did not doubt that there were a few small matters in which the State could help the commerce and industry of the country. But he did very earnestly hope that neither on the political side nor on the industrial side would there be a disposition to bring industry into Parliament. He did not mean industry as a virtue, but in its commercial aspect into close contiguity. He was sure it would be bad for both ; it would be bad for commerce and industry, because when they learned to depend upon something that Parliament had to do they would destroy that self-reliance which was so important, and they would find that after all they were relying on a body which, however well intentioned, had neither the opportunity nor the capacity to be of any great service to their cause. On the other hand, he would deprecate close relations between Parliament and the great industrial undertakings of this country. They had been kind enough to drink the health of the Houses of Parliament, but he could assure them that the Houses of Parliament, or the Members of them who were present, had come hither much more anxious about the health of Iron and Steel. They heard the most diverse and confused accounts of the health of those great industrial bodies. Some people said everything was going very well. Some people said mysteriously that iron was going, one knew not where, presumably to some industrial Gehenna, to which the way was paved with pearl buttons and cheap bread. He was incompetent to enter upon that controversial field. All that he contended for was that iron was after all wealth, and he had to confess that he viewed with some surprise the very different feelings with which people contemplated a ship laden with gold coming from South Africa and a ship laden with iron coming from America. He believed that in both cases our shores were the richer for the wealth that was brought to them. However, he was not a scientist, and liked to view those interesting minerals with an impartial eye. He could not help feeling that gold and iron had an interesting symbolism with which he might close his remarks. He did not believe in links of gold ; he did

not believe in binding together by links of self-interest; but he did believe in those links, strong and flexible, which might be compared with steel. He believed in sentimental connections; in the common patriotism which united a great Empire; and in that which bound them in a wider unity than any which could be comprised under any national title. The great British race which existed in two great communities was bound together by links of steel, and they were bound to remember that they who are Britons or Americans were inheritors of a common history, spoke a common language, and looked forward to a future of equal prosperity to come. He hoped the bonds that united the two great industrial peoples of the world might grow closer and closer, and that their banquet of that evening might fulfil its humble, if soon forgotten part, in the great task of international union.

The Rt. Hon. Sir EDWARD GREY said he agreed with Lord Hugh Cecil, that industry must be one of the great interests of the House of Commons. The House of Commons should be careful, at any rate, to do no harm, and it should, by simply knowledge and study, qualify itself to do all the good in its power. But the industry of this country must be based upon the enterprise of the manufacturers and the quality of the workmen. It must be based greatly upon the great mutual relations between those two; and though the House of Commons may help, and though the House of Commons should always be occupied with that subject, it was the employers and workmen themselves who would have to finally solve the problems of industry. The House of Commons' first duty was, he thought, to maintain liberty. Left to themselves, Governments encroach upon liberty. Corrected by the House of Commons they never transgress. The House of Commons should educate public opinion, and he thought it did so on matters of great national importance. Its performance of that duty is a little qualified by the fact that when a great matter of public policy has become exceedingly interesting a large number of Members of the House of Commons are not very anxious that it should come on for discussion. Economy, also, should be the object of the House of Commons. They had every reason to congratulate themselves that the House of Commons had worthy representatives of all the great interests.

Sir BENJAMIN HINGLEY, Bart., having proposed the toast of "The Guests,"

The EARL OF GLASGOW and Mr. SETH LOW (ex-Mayor of New York City) acknowledged the toast.

Professor H. LE CHATELIER, of Paris, said he regretted that his insufficient knowledge of English prevented him speaking in that tongue. It was not necessary in that room to recall the services rendered to industry by their celebrated institution. If ever the humanitarian dream of universal harmony should be realised, such international societies as theirs would certainly have a leading part in bringing it about.

They were aware that, along different lines, the French Society for the Encouragement of National Industry pursued the same object as the Iron and Steel Institute. He had been fortunate enough to induce his Society to undertake research in metallurgical science in which they took so great an interest. He had been inspired in this by his recollections of the earliest papers written by Sir Lowthian Bell on the chemistry of the blast-furnace, the reading of which had taught him what useful assistance science and industry can lend each other. They had taught manufacturers a valuable lesson by devoting so large a part of their work to research in applied science, and the names of some of their most illustrious members would remain as a permanent memorial of the marvellous results of co-operation in science and practice. Notwithstanding this, many captains of industry still hesitated to employ scientific methods in their works, possibly because their engineers, chemists, and mechanicians, trained in schools of science, had not always evinced the superiority in practice which was expected of them.

If the members of such an Institute would take the trouble, in every case in which science had apparently failed in the works, to trace the cause of this failure, and to communicate the results of their investigation, the problem would soon be solved. Industrial processes depended upon a great many different factors. The practical sense was the faculty of seizing at a glance the bearings of all the conditions and gauging their relative importance. In present scientific training, analytical methods were pushed to excess, and too often accustomed the intellect to look at only one side of things, and that side not always the most important one. This turn of the mind, which was opposed to the true scientific method, decidedly hampered industry. Teaching would gain in usefulness, if we abstained from giving it a practical stamp too soon. More truly scientific teaching would form more practical engineers. It should not be forgotten that all great scientific advances were due to men whose chief occupation led them to the study of Nature. Lavoisier, Fresnel, Sadi-Carnot were above all things practical men. And practical application had been the constant care of Lord Kelvin, their most illustrious man of science.

The Iron and Steel Institute had taken a large part in the development of scientific metallurgy ; its services to industry would be greater still if they could find a means whereby it might with greater facility apply the results of work already done to that advantage which they had a right to expect.

LORD ALVERSTONE, in proposing the "Iron and Steel Institute," said that the Institute had every reason to be proud of the achievements of its thirty-five years of life. He spoke not only of those that it had promoted to its ranks as Presidents and Vice-Presidents of this Council, of great men who were the leaders, some of them great pioneers, many of them great experts in the arts of iron and steel industry, but it had from the outset determined that its main policy and object should be to extend the cause of scientific education and to promote scientific research, and that, therefore, it had approached the question of preserving the interests of the industry which it represented, from the point of view of seeing how best it could bring to bear the discoveries of science upon the natural and ordinary occupations of commercial life in connection with that great industry. When he looked back at some of the names of those great men—some, he was glad to know, were present that night—he could not help feeling that it had been a great encouragement, a great source of strength to this Institute, that the great giants, scientifically and commercially, in these great industries, had been willing to come forward and to expend their time and devote their energies to forwarding the interests of the Institute. One name came back to him, mentioned in the eloquent speech of Professor Le Chatelier, as being one of the men who came to this country full of inventions, and bestowed upon this country the benefit of his magnificent intellect—he referred to Sir William Siemens, a man whom it had been his privilege to know most intimately. He had seen many of those many marvellous inventions in electricity, in the manufacture of steel, and in other matters, which had been the marvel of those who had been privileged to see the workings of Sir William Siemens' scientific mind. There was one other name he would like to mention in the long roll of Presidents, the man who, perhaps, had developed the steel industry more than any one else—Sir Henry Bessemer. If this had been the time and the place even, for a humble and retiring lawyer to describe any incidents in his career which had been brought into strong relief, and to impress upon his mind what had been the marvellous achievements of those men, to two of whom he had referred, he could, he thought, interest them by reminding them of what had

been done in the course of the last forty or fifty years, and how invention and commercial enterprise had revolutionised this great industry. He wished, in a few sentences, to commend to their notice the name of the great man who was to return thanks for this toast—their President, Mr. Andrew Carnegie. The lives of great men, their experience, their trials, their successes, were part of the heritage of nations. There was nothing that interested one more than to read accounts of how, from small beginnings, men have at times risen to greatness by their own efforts. They knew the practical interest which he had taken and shown in the Iron and Steel Institute in the years gone by, in the devotion of its energies to scientific education, and the encouragement of industry and research; and they knew that he had carried out the best sentiments and wishes of those who founded the Institute, and had in no small measure shown in a practical way how much he appreciated those worthy aims and objects of the Institute that ought to be encouraged. He did not confine his interests and his sympathies either to one side of the Atlantic or to one industry only. He had endeavoured to bring sunshine, light, and happiness into the lives and homes of many, whether it were by spreading the love of literature and the opportunity of acquiring knowledge among hundreds of thousands, or whether it were by the direct promotion of scientific research. He was satisfied that they would agree with him that Andrew Carnegie had indeed shown what ought to have been done by men who desire to set an example to the world of what a man of means, of culture, and education ought to do to benefit his fellow-men. In the speeches they had heard, there was one sentiment which struck them most, the desire expressed that the two nations, England and the United States, should go forward in the march of civilisation and the promotion of science, learning, peace, and goodwill. He asked them to join him in drinking not only “Prosperity to the Iron and Steel Institute,” but “Continued long life and happiness to the President, Mr. Carnegie;” and, if he might be allowed, he would add thereto, Mrs. and Miss Carnegie.

The PRESIDENT, in reply, said he rose to respond to the toast; and on behalf of the Institute, laudatory as were the words of the noble speaker, he accepted them, every word of them, as no more than due. It was emphatically a noble Institution. It had no secrets; it hid nothing. He had heard during the last two days two of the leading firms of the world each stating to the public exactly what they were doing, how they were doing it, and what the results were. And he



had heard that day another discussion in which two manufacturers took part in another line of the industry, telling everything that their experience had given them. These would be published in the records of the Institute, and would go all over the world. They in that Institute knew that it was not by every man keeping to himself what he did, but by a generous co-operation and an exposition of all that which he knew, that they received in turn benefits of a like nature. That was a feature of the Institute that had always charmed him. Their guests must know the extent of this Institute, and of its ramifications. They had members from nineteen different countries of the world; members in all parts of the world, speaking all the languages of the world; and there was nothing that could happen in any of those countries that was not reported to us, so that they carried with them the combined efforts of the whole world, and knew just where they stood. He thought that the Iron and Steel Institute was unique in that respect. If he had been the Chancellor of the Exchequer submitting a budget to them that night, he would be the envy of all the Chancellors of the Exchequers of all the countries of the world, and especially of the two countries of the English-speaking race, for he would have to report to them that their revenue last year had been the greatest upon record. He would have had to report that their expenditure had been the greatest also, but with this reservation, that not one dollar had been spent for destructive purposes; every dollar had gone for educative and scientific purposes. They had distributed of their surplus to kindred societies and to research scholars, more than ever had been done before in the history of the Institute. He would have had to report, as Chancellor, that they did not propose any additional taxation, and would not trouble them for another penny upon their incomes. There had never been so many members admitted to the Institute as during the last year; their birth-rate was increasing at an enormous rate. Last year he had had at his right the Prime Minister of his native land, and at his left the Ambassador of his adopted land. Metaphorically speaking, he had taken their hands, placed them in each other, and said, still metaphorically, to himself, "Whatever you do, don't let go that grasp." This Institute was not confined to the English-speaking race. The whole world was its empire; and one reason why they had a surplus revenue and were so prosperous, and had no fiscal question to bother them, was that they had no enemies. He looked upon the international mission they were performing in this Institute as perhaps only second to the scientific.

They met each other. They knew each other. They were friends from all lands. The only trouble about Britain and about America and other countries standing apart, was the result of ignorance of each other. If every man in Great Britain knew foreign nations as their king did, they would have a very different state of affairs. They were going to New York; the next meeting took place there. They would be received there not as strangers, but as Americans were received here. He had always told his fellow-countrymen of America that the heart of the people of Great Britain was kindly disposed, and that her sympathies were warm for the child-land. They would find all those feelings warmly reciprocated now. He hoped that nothing would ever occur that would mar the present most satisfactory condition of the national relations between the two lands. Instead of taking the two hands comprising the whole English-speaking race, he felt that they of the Institute were disposed to take the hands of all the representatives of all nations hands round, and never let that grasp go. They were to meet next time in New York. He would speak now as an Iron and Steel Institute President, and say there awaited them, over yonder, outstretched arms, and that they would be received as before; and he had no doubt that much knowledge that they would obtain would be beneficial; but a still greater harvest would be the sentiments of friendship evoked and returned, which would serve to bind together that which should never have been separated, the two branches of our English-speaking race.

The proceedings then terminated.

## OBITUARY.

FRIEDRICH BREMME, Director-General of the Upper Silesian Coke Company, died at Gleiwitz on January 29, 1904, aged sixty. He was educated at Cologne and at the Clausthal School of Mines, and was engaged for several years at the Ilseder works, at the Georgs-Marienhütte, and at Siegen. From 1883 to 1886 he was manager of Count Hugo Henckel's blast-furnaces, and from that date to 1891 he acted as general manager of the Julienhütte. In 1891 he took over the direction of the Upper Silesian Coke Works. He was on the board of directors of various iron and coal companies in Germany, Russia, and Hungary. He showed keen interest in local affairs, and was a member of the corporation of Gleiwitz. He helped to institute the technical society "Eisenhütte Oberschlesien," of which he was on the council until his death. He was elected a member of the Iron and Steel Institute in 1889.

GUSTAF EMIL BROMS died on October 18, 1903. He was a well-known Swedish financier and founder of the Gellivare and Kiirunavaara Iron Ore Companies. He was a Knight Commander of the Royal Order of Wasa. He was elected a member of the Iron and Steel Institute in 1899, and organised the visit to the mines of the Arctic circle in connection with the Stockholm meeting of the Institute in 1898.

EDWARD COWARD of Hetheringlea, Bowdon, died on April 10, 1904, at Eastbourne, in his seventy-third year. He was one of the firm of Meland and Coward of Manchester. He was a director of the Bleachers' Association, Ltd., and of the Royal Insurance Company. At one time he was chairman of the Ebbw Vale Steel, Iron, and Coal Company, Ltd., and a director of the Great Northern Railway and of the West Somerset Mineral Railways. He was for many years on the Board of the British Iron Trade Association, and was a member of the Institution of Mechanical Engineers and an associate of the Institution of Civil Engineers. He was elected a member of the Iron and Steel Institute in 1874.

RUSSELL WHEELER DAVENPORT died at Philadelphia on March 2, 1904, after a brief illness, aged fifty-five. He was born at Albany,

New York, and was educated partly in America and partly in Europe. He entered Yale in 1868, and the following year became assistant instructor in the chemical laboratory under Professor Oscar D. Allen. In 1872 he spent a year at Berlin University, and the following year visited the iron and steel works of Germany, France, and England. In 1874 he became the chemist of the Midvale Steel Co. in Philadelphia, and ultimately manager of the works. In 1884, under his management, the first successful steel forgings were manufactured at these works for the modern style of built-up cannon; and in 1888, when the Bethlehem Iron Co. began to operate their gun and armour-plate plant, he was placed in charge of this part of the works. He was recognised as a leading authority in the United States on these subjects. In January 1893 he was appointed second Vice-President of the Bethlehem Iron Co. Harvard conferred upon him the honorary degree of Master of Arts as a recognition of his acquirements as a metallurgist, and his own university, Yale, paid him the same honour. In October 1901 he resigned his position at Bethlehem and returned to Philadelphia. In June 1903 he became general manager of the William Cramp & Sons Shipbuilding Co. at Philadelphia, which position he held at the time of his death. He was a member of the American Society of Mechanical Engineers, and of the American Institute of Mining Engineers. He was elected a member of the Iron and Steel Institute in 1889.

CHARLES JOHN GALLOWAY died on March 14, 1904, at Knutsford, aged seventy-one. He was for many years an active member of Galloways, Limited, boilermakers and engineers of Manchester. He had the entire superintendence of the construction of the viaduct carrying the Furness Railway across Ulverston Sands, which at the time was considered an engineering feat of magnitude and daring. He took great interest in various international exhibitions, and was consulted by Sir Philip Cunliffe Owen about the arrangement of machinery in the British section of the Paris Exhibition of 1878. In recognition of his services he was made a Knight of the Legion of Honour. After the Paris Exhibition of 1899, with which he was also connected, he became an officer of that Order. He took part in the origination and management of the Manchester Royal Jubilee Exhibition of 1887. In the preceding year he joined the ship-canal movement, and shortly afterwards became a director of the company, retaining that position until his death. He was chairman of the Vulcan Boiler and General Insurance Co., Ltd., and a director of Brunner, Mond, & Co., Ltd., the Carnforth Hæmatite Iron

Co., Ltd., the Commercial Union Co., Ltd., and the Mond Nickel Co., Ltd. He was possessed of great artistic taste, and was a liberal patron of the fine arts. He was a Justice of the Peace for Manchester and for the county of Chester. He was a member of the Institution of Civil Engineers and of the Institution of Mechanical Engineers, and was elected a member of the Iron and Steel Institute in 1871.

HENRY WILLIAM HOLLIS died at Norbiton, Surrey, on December 3, 1903, at the age of sixty-six years. He played an important part in the development of the Weardale Iron, Steel, and Coal Company at Spennymoor, of which firm he was formerly manager, and it was under his direction that the firm advanced to a position of great influence in the industrial world. On his retirement some years ago he was elected a director of the company. He was a director of the Cargo Fleet Iron Co., Ltd., and of the Talbot Continuous Steel Process, Ltd. He was a well-known member of the Iron and Steel Institute, of which he was elected a member in 1880, and he contributed to the Institute's proceedings papers on "The Tudhoe Works of the Weardale Iron and Coal Company, Limited," in 1893, and on "The 'Weardale' Furnace" in 1897.

EDWIN JONES, the senior partner in the firm of Bayliss, Jones, & Bayliss, of Wolverhampton, died on February 18, 1904, at his residence, Wyvelsfield, Chislehurst. He entered the works at Wolverhampton as a young man, and on his marriage a few years later with the daughter of Mr. William Bayliss, became a member of the firm. He afterwards came to London, where he carried on the London agency, and in 1901 became a director of the newly-formed company. He was also closely connected with the coal industries of South Wales. His business career was most successful. He was placed on the Commission of the Peace for Glamorganshire, and subsequently invited to stand for Bridgend. He was elected a member of the Iron and Steel Institute in 1881.

JONAS LINDLOW died at his residence at Ingwell, Cumberland, in January 1904, at the age of fifty-seven. He was a member of a well-known family of Cumberland ironmasters and landowners. He was a Justice of the Peace, and was elected a member of the Iron and Steel Institute in 1874.

WALTER GEORGE McMILLAN, Secretary of the Institution of Electrical Engineers, died at his residence at Streatham on May 16, 1904, at the

age of 43. He was educated at King's College School and King's College, and on leaving school he devoted his attention to metallurgy, after a short interval spent in the office of an accountant. He became private assistant to Professor Huntington at his old college, at which, in 1883, he was appointed demonstrator. In 1888 he obtained an appointment under the Indian Government as chemist and metallurgist to the Cossipore Ordnance Factories near Calcutta, which he held for five years. On his return to England he was appointed lecturer in metallurgy at the Mason College, Birmingham. In 1897 he was appointed to the Secretaryship of the Institution of Electrical Engineers, a position he continued to hold until his death. He was well known as a writer on subjects connected with electro-metallurgy, and was the author of two books dealing with electro-metallurgy and electro-plating respectively, as well as of articles in the supplement to the *Encyclopædia Britannica*. He was a vice-president of the South Staffordshire Institute of Iron and Steel Works Managers, and on the occasion of the visit of the Iron and Steel Institute to Birmingham in 1895 he organised an exhibition illustrating the industries of Birmingham, for which he received the thanks of the members. He prepared for the Institute Journal a detailed catalogue of this exhibition. To the transactions of the Institute he also contributed, in 1894, a paper on colour-gauges for carbon testing. He was elected a member of the Iron and Steel Institute in 1894.

GEORGE PEARS died at his residence, Witton House, Witton-le-Wear, in March 1903, aged eighty-two. He was a coalowner with extensive interests in Durham, Yorkshire, and Derbyshire, and conducted the commercial business of several collieries. He was well known on the Newcastle and Middlesbrough Exchanges, and was elected a member of the Iron and Steel Institute in 1877.

HENRY WILLIAM PEARSON died on October 20, 1903, at the age of fifty-seven years. He was born in 1856, and commenced his professional career in 1862 at the Great-Eastern railway works at Stratford in the locomotive department of the works. He was a member of the Institution of Civil Engineers and of the Institution of Mechanical Engineers. He was elected a member of the Iron and Steel Institute in 1900.

FRIEDRICH SIEMENS died at his residence in Dresden on May 24, 1904. Born at Menzendorf near Lübeck in 1826, he was a member of one of 1904.—i.

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the most remarkable families in Germany, almost all of whom subsequently became famous in the realm of applied science. In 1848 he proceeded to England, and was occupied with the introduction of the telegraphic apparatus devised by his brother, Dr. Werner von Siemens. He then worked for many years with his brother, Sir William Siemens. He was the inventor of the application of the regenerative principle to the open-hearth furnace, and on the first patent (No. 2861) granted in England on December 2, 1856, his name alone appears. The importance of this invention to the steel industry is shown by the fact that in the year 1902 the production of open-hearth steel in the United States, Germany, and Great Britain amounted to 11,462,096 tons. On his marriage in 1864, Friedrich Siemens took up his residence in Berlin and devoted his attention to the introduction of his furnace on the continent. On the death of his brother Hans he took over the glass-works he had founded in Dresden. The glass furnace invented by him forms the basis of the modern system of glass manufacture. In 1880 he devised an improvement in his regenerative furnace by the employment of the free flame and high arch. A few years ago he devised a new regenerative system, in which a portion of the heated products of combustion are converted into fuel gas that can be conducted under the grate of the gas producer in place of cold air. He was also the inventor of the regenerative gas burner, and of many important appliances in glass manufacture. In recognition of his many important inventions he received on April 23, 1900, the honorary degree of Doctor of Engineering at Dresden. He was elected a member of the Iron and Steel Institute in 1884, and contributed to its proceedings papers on combustion in 1883, and on a new method of heating the regenerative furnace in 1884.

JOHN STEVENSON, of Norwood Lodge, Grove Hill, Middlesbrough, died on April 10, 1903, at the age of seventy-three. He was well known in the North of England as a man of consummate business ability, to whom the development of mining and metallurgical interests on the Tees owed much. In association with Mr. Joseph Dodds and the late Mr. R. M. Jacques, he joined the establishment of the Acklam Ironworks, one of the most important undertakings in the North of England; and on the dissolution of this firm, he entered into partnership with Mr. W. H. Cooper as coal and iron merchants, the business being ultimately carried on by himself and his son. He was managing director of the Framwellgate Moor Collieries and of the Grinkle Park Ironstone Mines. He

was an enthusiastic Volunteer, being commanding officer of the 1st N. R. Y. Volunteer Artillery, and a Justice of the Peace for Middlesbrough. He was for many years an active supporter of the Iron and Steel Institute, of which he was an original member, having been elected in 1869.

JAMSETJEE NUSSERWANJEE TATA died on May 19, 1904, at Bad Nauheim. He was a well-known millionaire and philanthropist of Bombay, and he devoted a considerable portion of the large fortune which he had acquired to public objects intended for the benefit of the people of India and for the development of Indian industrial resources. He also spent large sums of money in endeavouring to improve the staple of Indian cotton, and also on the improvement of sericulture in Mysore, and offered the Government of India, on certain conditions, the enormous sum of £150,000 for the endowment of research. The conditions of the offer were such as, up to the present date, to prevent the Government from accepting it. It is, however, understood that the offer is still open, the amount of the endowment being left in the hands of trustees, who have power to negotiate with the Government of India for its application. He enjoyed a very high reputation among both his fellow-countrymen and Anglo-Indians for his liberality, and the assistance he was always ready to give to useful charities will be greatly missed. He was a member of the Society of Arts, and was elected a member of the Iron and Steel Institute in 1902.

JAMES P. WITHEROW died on March 13, 1904, at Pittsburg, after a short illness. He was well known in America as an engineer, and under the name of Witherow & Gordon carried on a blast-furnace engineering business. He also managed large foundry and machine shops in Newcastle. He was an authority on questions of blast-furnace practice, and contributed numerous papers upon this and other subjects to the American Institute of Mining Engineers—notably on the Clapp-Griffiths process, and on the manufacture of steel in small converters. He was elected a member of the Iron and Steel Institute in 1884.

GEORGE WILKINSON, of the Tividale Steel Mills, Tipton, died on January 10, 1904. He was for over fifty years actively connected with the metallurgical industries of South Staffordshire, having been associated with the late Mr. Samuel Blackwell at Dudley, and afterwards becoming a partner in the firm of Messrs. J. T. & W. E. Johnson, West Bromwich. He was elected a member of the Iron and Steel Institute in 1882.



**WILLIAM WILLIAMS**, of Maesygwernen Hall, Morriston, South Wales, died in April 1904. He was the son of a working man at Morriston, and began work at the age of eleven or twelve as roller boy in a local tinplate works at a wage of five shillings a week. After an unfortunate accident, followed by the amputation of his left leg, his employers found him a place in the office, where he speedily made his services valuable. In 1863 he was appointed manager of the Swansea Tinplate Works, then owned by Sir John Jones Jenkins, and subsequently starting in business on his own account he became chief proprietor and manager of the extensive works at Morriston, and retired at an early age as a very wealthy man. He was a director of the Capital and Counties Bank, Ltd., of the Swansea and Mumbles Railways, Ltd., and of the Swansea Gas Light Co. He was elected Mayor of Swansea, and eventually was elected unopposed as Parliamentary representative of the district. Owing to ill-health, however, he was compelled to retire after a brief political career. He was elected a member of the Iron and Steel Institute in 1882.

# ADDITIONS TO THE LIBRARY

## DURING THE FIRST HALF OF 1904.

Title.	By whom Presented.
"The Analytical Chemistry of Uranium." By H. Brearley. 8vo, pp. 45. London. 1903.	Longmans, Green & Co.
"Ankylostomiasis: its Cause, Treatment, and Prevention." 4to, pp. 31. London. 1903.	The Manager, <i>Colliery Guardian</i> .
"A Comparison of Certain Physical Properties of Nickel Steel and Carbon Steel, proving the Superiority of Nickel Steel over Carbon Steel for Bridge and Structural Purposes." By A. Ladd Colby. 4to, pp. 103. Bethlehem, Pa. 1903.	The Author.
"Annual Report of the Chief of the Bureau of Steam Engineering, 1903." 8vo, pp. 67. Washington, D.C. 1903.	The Director.
"Subject List of Works on the Mineral Industries and Allied Sciences in the Library of the Patent Office." 16mo, pp. 302. London. 1903.	The Comptroller-General.
"Das Kalibrieren der Walzen," No. 3. By A. Brovot. Folio. Leipzig. 1903.	The Publishers (A. Felix).
"Practical Advertising," 1903-4. 4to, pp. 688. London. 1903.	Mather & Crowther.
"Wärmeverluste bei Dampfkesseln." By O. Binder. (Published in <i>Der Papier-Fabrikant</i> , 1903, pp. 609-611.)	The Author.
"Colonial Import Duties, 1903. Return relating to the Rates of Import Duties levied upon the Principal and other Articles imported into the Colonies and other Possessions of the United Kingdom." 8vo, pp. 479. London. 1903.	Board of Trade.
"Statically Indeterminate Structures." By J. Kruger. 8vo, pp. 16. London. 1903.	The Author.
"The Incorporated Accountants' Year-Book, 1903-1904." 8vo, pp. 537. London. 1903-1904.	The Society of Accountants.
"Ueber die Bedeutung der ausländischen Eisenerze für die Deutsche Hochofenindustrie." By A. Weiskopf. 4to, pp. 2. (Reprinted from <i>Mitteilungen des Hannoverschen Bezirksvereins Deutscher Ingenieure</i> , No. 24, December 3, 1903.) Hanover. 1903.	The Author.
"Explanatory Note to the Geological Map of the Southern Transvaal." By F. H. Hatch. 8vo, pp. 14. London. 1903.	E. Stanford (Publishers).
"Die Grundlagen der Russischen Eisenindustrie." By E. Holtz. 4to, pp. 15. Berlin, 1903.	The Author.
"Colonial Import Duties, 1903. Statement of the Rates of Import Duties levied in European Countries, in the United States, in Japan, and in China, upon the Produce and Manufactures of the United Kingdom." 8vo, pp. 467. London. 1903.	Board of Trade.
"Tasmania. Report of the Secretary for Mines, 1901-1902." 8vo, pp. 303. Tasmania. 1902.	The Agent-General.

Title.	By whom Presented.
"The Mineral Industry of Tasmania for the Quarter ending September 30, 1902 (8vo, pp. 19), and for the Quarter ending December 31, 1902 (8vo, pp. 23)." Tasmania. 1902 1903.	The Agent-General.
"The Mineral Resources of the State of Rio Grande do Sul, Brazil." By H. K. Scott. 8vo, pp. 20. (Paper read before the Institution of Mining Engineers, July 2, 1903.) Newcastle-on-Tyne. 1903.	The Author.
"Mines and Quarries: General Report and Statistics. Advance Proof of the Tables of Fatal Accidents and Deaths in and about the Mines and Quarries of the United Kingdom during the Year 1903." Fol., pp. 9. London. 1904.	The Under-Secretary of State.
"The Metallurgy of Steel." By F. W. Harbord; with a section on "The Mechanical Treatment of Steel," by J. W. Hall. 8vo, pp. 758, with 178 figures, 280 illustrations in the text, and 100 microphotographs of steel sections. London. 1904.	The Authors.
"Suggestions for Increase of Trade between Great Britain and Her Colonies, &c., and a Fiscal Policy with other Countries." By Thomas Davie. 8vo, pp. 12. Coatbridge. 1904.	The Author.
"Eisen- und Stahlerzeugung im Elektrischen Ofen." By H. Goldschmidt. 4to, pp. 15. (Reprinted from the <i>Zeitschrift für Elektrochemie</i> , No. 32, 1903.)	The Author.
"Über Brikettierung von Eisenerzen." By A. Weiskopf. 8vo, pp. 15. Vienna. 1903.	The Author.
"Chemische Reaktionen bei extrem hohen Temperaturen." By C. Zenghelis. 8vo, pp. 6. (Reprinted from <i>Zeitschrift für physikalische Chemie</i> , vol. xlv.) Leipzig. 1903.	The Author.
"Estudios sobre los Carbones de Teruel y especialmente sobre la Cuenca de Utrillas." By Antonio Gascon. 8vo, pp. 170. Madrid. 1903.	Bennett H. Brough.
"Microscopic Analysis of Metals." By F. Osmond and J. E. Stead. 8vo, pp. 178 (with 100 photographic illustrations and two folding diagrams). London. 1904.	The Authors.
"Metallurgy as Applied to Engineering." By A. P. Head. 8vo, pp. 22. London. 1904.	The Author.
"Album of Drawings Relating to the Manufacture of Open-Hearth Steel." By M. A. Pavloff. Fol., containing 52 drawings. Ekaterinoslav. 1904.	The Author.
"Shipping World Year-Book, 1904." 8vo, pp. 1256. London. 1904.	The Editor.
"La Reunion del Institute del Hierro y el Acero en Barrow-in-Furness." By J. de Lazúrtegui. 8vo, pp. 42. Bilbao. 1903.	The Author.
"British Corporation for the Survey and Registry of Shipping." Additions and Corrections. February 1904. Glasgow. 1904.	The Secretary.
"Traité Théorique et Pratique de Métallurgie Générale." By L. Babu. 8vo, pp. 588. Paris. 1904.	The Author.
"Report of the Ninth Meeting of the Australasian Association for the Advancement of Science." 8vo, pp. 866. Hobart. 1903.	The Secretary.
"Second Annual Report of the Andrew Carnegie Relief Fund, 1903. Disbursements and General Notice to Employers." Pittsburg. 1904.	The Manager.
"Report of the Select Committee on Ventilation appointed by the House of Commons." 8vo, pp. 31. London. 1904.	The Committee.

Title.	By whom Presented.
"The Cost of Open-Hearth Steel as Affected by using Blast-Furnace Gas in Gas-Engines and Remarks on the Latest Improvements." By P. Eyermann. 8vo, pp. 13. (Reprinted from <i>Journal of the Association of Engineering Societies</i> , vol. xxxi., September 1903.)	The Author.
"Open-Hearth Steel Making and Blast-Furnace Gas in Gas-Engines." By P. Eyermann. Fol., pp. 6. ( <i>Iron Trade Review</i> , October 22, 1903.)	The Author.
"Mysore Geological Department. Report of the Chief Inspector of Mines for the period January to June 1903, with Statistics for the Year 1902." Fol., pp. 66. Bangalore. 1903.	The Director.
"Compte Rendu des Séances du 27th Congrès des Ingénieurs en Chef des Associations de Propriétaires d'appareils à Vapeur tenu à Paris en 1903." 8vo, pp. 231. Paris. 1904.	The Secretary.
"The University of Colorado Studies." Vol. I., No. 4. 8vo, pp. 269-363. Boulder, Colorado. 1904.	The Secretary.
"Meteoric Iron which Fell near Cabin Creek, Johnson County, Arkansas, March 27, 1886." By G. F. Kunz. 8vo, pp. 8. (Reprinted from the <i>American Journal of Science</i> , vol. xxxiii. 1887.)	G. F. Kunz.
"On Two Meteoric Irons." By G. F. Kunz and E. Weinschenk. 8vo, pp. 4. (Reprinted from the <i>American Journal of Science</i> , vol. xliii. 1892.)	
"Description of a Meteorite from Green County, Tennessee." By W. P. Blake. 8vo, pp. 6. (Reprinted from the <i>American Journal of Science</i> , vol. xxxi. 1886.)	
"Farmington, Washington County, Kansas Aerolite." By G. F. Kunz and E. Weinschenk. 8vo, pp. 4. (Reprinted from the <i>American Journal of Science</i> , vol. xliii. 1892.)	
"Effects on Rare Earth Oxides Produced by Radium-Barium Compounds and on the Production of Permanently Luminous Preparations by Mixing the Latter with Powdered Minerals." By C. Baskerville and G. F. Kunz. 8vo, pp. 2. (Reprinted from the <i>American Journal of Science</i> , vol. xvii. 1904.)	
"Biographical Notice of Thomas Egleston." By G. F. Kunz. 8vo, pp. 22. New York. 1901.	The Author.
"Biographical Notice of Heber R. Bishop." By G. F. Kunz. 8vo, pp. 6. Lancaster, Pa. 1903.	
"Electricity on the Oil-Fields." By L. Gaster. 4to, pp. 7. London. 1904.	The Author.
"Die Königlich Sächsische Bergakademie zu Freiberg." 4to, pp. 81. Freiberg. 1904.	Professor A. Ledebur.
"Mines and Quarries: General Report and Statistics. Advance Proof of the Tables relating to the Output of Coal and other Minerals and the Number of Persons Employed during the Year 1903." Fol., pp. 11. London. 1904.	The Under-Secretary of State.
"House of Commons: Speech by Sir James Kitson on February 9, 1904, on King's Speech (Motion for an Address)." 8vo, pp. 4. London. 1904.	Sir James Kitson, Bart., M.P.
"Ausführliches Handbuch der Eisenhüttenkunde." By Dr. H. Wedding. 8vo, pp. 348. Brunswick. 1904.	The Publishers.
"Das Roheisen mit besonderer Berücksichtigung seiner Verwendung für die Eisengiesserei." By A. Ledebur. 8vo, pp. 104. Leipzig. 1904.	The Author.
"Über den Export von Schwefelkies und Eisenerz aus norwegischen Häfen." By A. Weiskopf. (Reprinted from the <i>Zeitschrift für praktische Geologie</i> , vol. xii. pp. 94-97.)	The Author.

Title.	By whom Presented.
"Canadian Trade Index." 8vo, pp. 332. Toronto. 1904.	The Canadian Manufacturers' Association.
"High-Speed Tool Steel, its Manufacture and Use." By J. M. Gledhill. 4to, pp. 44. (Paper read before the Coventry Engineering Society, March 4, 1904.) Manchester. 1904.	The Author.
"The New Engineering Works of Graham, Morton & Co., Ltd., Leeds." By J. Cassidy. Fol., pp. 8. (Reprinted from the <i>Journal of Gas Lighting</i> , March 15, 1904.)	The Editor, <i>Journal of Gas Lighting</i> .
"Jahrbuch der Schiffbautechnischen Gesellschaft." Vol. IV., 4to, pp. 708; Vol. V., 4to, pp. 570. Berlin. 1903-1904.	H. Bauerman.
"Transformations Allotropiques des Aciers au Nickel." By O. Boudouard. 4to, pp. 10. (Extrait de la <i>Revue de Metallurgie</i> , vol. i., February 1904.) Paris. 1904.	The Author.
"The Production of Iron and Manganese Ores in 1902." By John Birkinbine. 8vo, pp. 37 and 47 respectively. Washington, D.C. 1904.	The Author.
"Distribution of Lake Superior Iron Ores, with Map." By John Birkinbine. 4to, pp. 4. Washington, D.C. 1904.	The Author.
"Second Report of the Royal Commission on Coal Supplies." Vol. I.—The Report (fol., pp. v.) Vol. II.—Minutes of Evidence and Appendices (fol., pp. 419). London. 1904.	The Secretary.
"Supplement to the Second Report of the Royal Commission on Coal Supplies." Containing 28 plans and diagrams. Fol. Vol. III. London. 1904.	The Secretary.
"An Explosion of High Grade Ferro-Silicon." By G. Watson Gray. 8vo, pp. 3. (A Note read before the Faraday Society, February 2, 1904.) London. 1904.	The Author.
"On the Location and Examination of Magnetic Ore Deposits by Magneto-metric Measurements." By E. Haanel. 8vo, pp. 132. Ottawa. 1904.	The Author.
"Some Neglected Aspects of the Fiscal Question." By John Shanks. 8vo, pp. 32. Glasgow. 1904.	The Author.
"Welches Rohr verwende ich?" By C. Ritter von Schwarz. 8vo, pp. 57. Jena. 1904.	The Author.
"The Iron Ore Deposits in Sydvaranger, Norway." By G. Henriksen. 8vo, pp. 8. Christiania. 1904.	The Author.
"Monmouthshire Iron and Steel Trade, Labour, and Wages Sixty Years Ago, Reminiscences of the Chartist Riots, &c." By Col. T. Mitchell. 8vo, pp. 26. Newport, Mon. 1904.	John Parry.
"Engineering Journal of the University of Birmingham." Vol. II., No. 5. May, 1904.	Professor T. Turner.
"Recherches Physiques et Physico-Chimiques sur l'acier au Carbone." By C. Benedicks. Upsala. 1904.	The Author.
Framed Photograph of the Annual Dinner of the Iron and Steel Institute, May 1904.	Fradelle & Young.
"A Century of British Trade." Chart. London. 1904.	The Proprietors, <i>British Trade Review</i> .
"Instructions for the Management of the Blow-pipe and Chemical Tests, with an Appendix from Berzelius." Third Edition. By J. Mawe. 16mo, pp. 71. London. 1822.	L. P. Sidney.
"A Treatise on the Progressive Improvement and Present State of the Manufactures in Metals." Vols. I. (8vo, pp. 341) and II. (8vo, pp. 362)—Iron and Steel. By D. Lardner. London. 1831.	L. P. Sidney.
"Bulletins of the Mysore Geological Department." No. I. (8vo, pp. 22)—Mine Signalling. No. II. (8vo, pp. 48)—Air Blasts and Quakes on the Kolar Gold Field. Bangalore. 1904.	W. F. Smeeth.

Title.	By whom Presented.
"Wm. Cooke & Co., Ltd., Sheffield, Directors' Report and Accounts for the Year ending March 31, 1904."	Thomas Wilkinson.
"Mines and Quarries: General Report and Statistics for 1902. Part IV.—Colonial and Foreign Statistics." Fol., pp. 493. London. 1904.	The Under-Secretary of State.
"Annual Report of the Minister of Mines for British Columbia for the Year ending December 31, 1903." 8vo, pp. 275. Victoria, B.C. 1904.	The Department of Mines, B.C.
"Boletín del Cuerpo de Ingenieros de Minas del Perú." No. 9. 8vo, pp. 43.	The Director.
"British Engineering Standards Coded Lists, issued by authority of the Engineering Standards Committee." Vol. I.—Rolled Sections for Constructional Iron and Steel Tram Rails. 4to, pp. 475. London, 1904.	Robert Atkinson.
"Lectures on Iron-Founding." By Professor T. Turner. 8vo, pp. 136. London. 1904.	C. Griffin & Co., Ltd.
"Subject List of Works on Electricity, Magnetism, and Electro-Technics in the Library of the Patent Office." 16mo, pp. 286. London. 1904.	The Comptroller-General.
"Memorandum as to the Wear of Rails." By Sir Lowthian Bell, Bart. No. I., fol., pp. 84; York, 1896. No. II., fol., pp. 147; Leeds, 1900.	The Author.
"Iron Ore Mining in Scandinavia." By W. Fischer Wilkinson. 8vo, pp. 17. (Paper read before the Institution of Mining and Metallurgy, June 16, 1904.)	The Author.
"Chemical Specifications for Pig Iron." By B. F. Faekenthal. 8vo, pp. 5. (Paper read before the American Institute of Mining Engineers, February 1904.)	The Author.
"The History of the Thomas Iron Company, 1854-1904." Fol., pp. 98. New York. 1904.	The Company.
"Mines and Quarries: General Report and Statistics for 1903. Part I.—District Statistics." Fol., pp. 47. London. 1904.	The Under-Secretary of State.

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H.M. Patent Office.	Royal Statistical Society.
Institution of Civil Engineers.	Royal United Service Institution.
Institution of Electrical Engineers.	Society of Arts.
Institution of Mechanical Engineers.	Society of Chemical Industry.
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Institution of Naval Architects.	University College.

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 in Scotland.  
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 Manchester Geological and Mining Society.  
 Merchant Venturers' Technical College  
 (Bristol).  
 Mining Institute of Scotland.  
 North-East Coast Institution of Engineers.

North of England Institute of Mining and  
 Mechanical Engineers.  
 Royal Dublin Society.  
 Sheffield Technical School.  
 South Staffordshire Iron and Steel Insti-  
 tute.  
 South Staffordshire Ironmasters' Associa-  
 tion.  
 South Wales Institute of Engineers.  
 University College of South Wales.  
 West of Scotland Iron and Steel Insti-  
 tute.

## COLONIAL AND FOREIGN.

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Australasian Institute of Mining En-  
 gineers.  
 Canadian Institute.  
 Canadian Mining Institute.  
 Canadian Society of Civil Engineers.  
 Department of Mines, Melbourne.  
 Department of Mines, Sydney.  
 Geological Survey of Canada.  
 Geological Survey of India.  
 Geological Survey of New South Wales.  
 Mining Society of Nova Scotia.  
 Royal Society of New South Wales.

## United States.

American Association for the Advance-  
 ment of Science.  
 American Foundrymen's Association.  
 American Institute of Mining Engineers.  
 American Iron and Steel Association.  
 American Society of Civil Engineers.  
 American Society of Mechanical Engineers.  
 Department of Labour.  
 Engineers' Society of Western Pennsyl-  
 vania.  
 Franklin Institute.  
 Massachusetts Institute of Technology.  
 New York Academy of Sciences.  
 Ordnance Office, War Department.  
 School of Mines, Columbia College, New  
 York.  
 Smithsonian Institution.  
 United States Geological Survey.

## Austria.

K.K. geologische Reichsanstalt.  
 Oesterr. Ingenieur- und Architekten-  
 Verein.

## Belgium.

Association des Ingénieurs sortis de l'École  
 des Mines de Liège.  
 Ministère de l'Intérieur.

## France.

Comité des Forges.  
 "Revue Maritime." Ministère de la  
 Marine.  
 Société d'Encouragement pour l'Industrie  
 Nationale.  
 Société de l'Industrie Minière.  
 Société des Anciens Élèves des Écoles  
 Nationales d'Arts et Métiers.  
 Société des Ingénieurs Civils.  
 Société Scientifique Industrielle de Mar-  
 seille.

## Denmark.

Tekniske Foreningen.

## Germany.

Königliche Bergakademie in Freiberg.  
 Königliche Technische Versuchsanstalt.  
 Verein Deutscher Eisenhüttenleute.  
 (Journal "Stahl und Eisen.")  
 Verein Deutscher Ingenieure.

## Italy.

Reale Accademia dei Lincei.

## Sweden.

Geological Institution of the University of  
 Upsala.  
 Jernkontoret.

# JOURNALS.

The following periodicals have been presented by their respective Editors :—

## UNITED KINGDOM.

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| <p>" Automobile Club Journal."<br/>         " British Fire Prevention Committee."<br/>         " Coal and Iron."<br/>         " Colliery Guardian."<br/>         " Contract Journal."<br/>         " Electrical Engineer."<br/>         " Electrician."<br/>         " Electro-Chemist and Metallurgist."<br/>         " Engineer."<br/>         " Engineer and Iron Trades Advertiser."<br/>         " Engineering."<br/>         " Engineering Review."<br/>         " Hardware Trade Journal."<br/>         " Hardwareman."<br/>         " Horological Journal."<br/>         " Iron and Coal Trades Review."<br/>         " Iron and Steel Trades Journal."<br/>         " Iron Trade Circular."</p> | <p>" Ironmonger."<br/>         " London Technical Education Gazette."<br/>         " Machinery Market."<br/>         " Marine Engineer."<br/>         " Mechanical Engineer."<br/>         " Navy League Journal."<br/>         " Page's Magazine."<br/>         " Petroleum Review."<br/>         " Phillips' Monthly Register."<br/>         " Plumber and Decorator."<br/>         " Practical Engineer."<br/>         " Quarry."<br/>         " Railway World."<br/>         " Science and Art of Mining."<br/>         " Shipping World."<br/>         " Statist."<br/>         " Tool and Machinery Register."</p> |
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## COLONIAL AND FOREIGN.

### Colonial.

- " Canadian Mining Review."  
 " Indian Engineering."

### United States.

- " American Journal of Science."  
 " American Machinist."  
 " American Manufacturer."  
 " Bradstreet's."  
 " Cassier's Magazine."  
 " Engineering and Mining Journal."  
 " Engineering Magazine."  
 " Engineering News."  
 " Iron Age."  
 " Iron and Steel Magazine."  
 " Iron Trade Review."  
 " Machinery."  
 " Mines and Minerals."  
 " Railroad Gazette."

### Austria.

- " Oesterr. Zeitschrift für Berg- und Hüttenwesen."

### Belgium.

- " Bulletin de l'Union des Charbonnages de Liège."  
 " Moniteur des Intérêts Matériels."  
 " Revue Universelle des Mines."

### France.

- " Annales des Mines."  
 " L'Echo des Mines."  
 " Le Génie Civil."  
 " Le Mois Scientifique et Industriel."  
 " Portefeuille Économique."

### Germany.

- " Annalen für Gewerbe und Bauwesen."  
 " Chemiker Zeitung."  
 " Glückauf."  
 " Verein Deutscher Eisen- und Stahl Industrieller."  
 " Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."  
 " Zeitschrift für praktische Geologie."  
 " Zeitschrift für Werkzeugmaschinen und Werkzeuge."

### Italy.

- " L'Industria."  
 " Rassegna Mineraria."

### Spain.

- " España."  
 " Revista Minera."

### Sweden.

- " Teknisk Tidskrift."





## SECTION II.

# *NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.*

## CONTENTS.

	PAGE		PAGE
IRON ORES . . . . .	462	FURTHER TREATMENT OF IRON AND	
REFRACTORY MATERIALS . . . . .	496	STEEL . . . . .	638
FUEL . . . . .	501	PHYSICAL PROPERTIES . . . . .	647
PRODUCTION OF PIG IRON . . . . .	562	CHEMICAL PROPERTIES . . . . .	675
PRODUCTION OF MALLEABLE IRON . . . . .	602	CHEMICAL ANALYSIS . . . . .	680
FORGE AND MILL MACHINERY . . . . .	607	STATISTICS . . . . .	691
PRODUCTION OF STEEL . . . . .	617	BIBLIOGRAPHY . . . . .	724

In the preparation of these Notes the Editor has been assisted by E. J. BALL, Ph.D.,  
Assoc. R.S.M., and H. G. GRAVES, Assoc. R.S.M.

# IRON ORES.

## CONTENTS.

	PAGE
I. Occurrence and Composition . . . . .	462
II. Iron Ore Mining . . . . .	486
III. Mechanical Preparation . . . . .	490
IV. Metallurgical Preparation . . . . .	495

### I.—OCCURRENCE AND COMPOSITION.

**Formation of Ore Deposits.**—S. F. Emmons\* considers historically the theories of ore deposition, and compares the ideas enunciated by the various writers on this subject. At first sight the wide divergence in the views expressed might seem to show that a universal agreement on accepted theories is as far distant as ever it was, but more mature consideration shows that advance in this direction has been real and permanent as regards the later stages of ore formation, which are more susceptible of actual proof. Disagreement lies rather with the ultimate or more theoretical sources of derivation, which must always remain matters of opinion.

H. P. Gillette† discusses osmosis as a factor in the formation of ore deposits. Osmotic pressure, which may be calculated on the lines enunciated by Van't Hoff, supplemented possibly by convection currents, will force the dissolved mineral through all possible passages, and the deposition will be progressively more rapid where the cooling effect is greatest, that is, in the larger cracks which occur at the intersection of fissures and similar larger openings.

J. F. Kemp‡ reviews the recent general literature on ore deposits, dealing with the primary derivation and distribution of the metals in

\* *Bulletin of the Geological Society of America*, vol. xv. pp. 1-28.

† *Transactions of the American Institute of Mining Engineers*, October 1903.

‡ *The Mineral Industry*, New York, vol. xi. pp. 632-638.

the earth, the primary concentration of the metals in veins and other ore deposits, and the secondary changes, re-arrangements and enrichments of ore deposits,

V. Novarese \* also reviews the recent literature on the formation of ore deposits.

The modern theories concerning ore deposits are discussed by G. A. Waller.†

F. Klockmann ‡ discusses the recent views propounded regarding the contact-metamorphic magnetite deposits, their formation and systematic position.

The geological association of iron ore and phosphorus is discussed by L. de Launay. §

E. Harbort || discusses the origin of certain Devonian red hæmatite deposits.

A. Sachs ¶ has written an important paper on the formation of the ore deposits of Upper Silesia. He shows that the deposits in their present form are epigenetic, that the ore was introduced from above by concentration of the originally finely disseminated ore, that the adjacent rock was converted into dolomite simultaneously with the introduction of the iron, zinc, and lead ore solutions, and that Bernhardt's theory of reduction may be adopted for the concentration of the ores in fissures. This theory is that the reduction of sulphates to sulphides is due to the products of the volatilisation of coal.

**Mineralogical Characteristics of Iron Ore.**—Attractive coloured plates of specimens of iron ores, manganese ores, and meteorites selected from Continental museums are given in Reinhard Brauns' work on mineralogy.\*\* The use of iron ore in jewellery is described in M. Bauer's work on precious stones, †† of which an English translation by L. J. Spencer has been published. ‡‡

G. W. McKee §§ describes some crystals of hæmatite having well developed prismatic faces. The measurements are given in detail and a gnomonic projection is reproduced.

\* *Rassegna Mineraria*, vol. xx. pp. 113-115.

† *Report of the Ninth Meeting of the Australasian Association*, pp. 205-250.

‡ *Zeitschrift für praktische Geologie*, vol. xii. pp. 73-85.

§ *Comptes Rendus*, vol. cxxxviii. pp. 225-227.

|| *Neues Jahrbuch für Mineralogie*, 1903, vol. i. pp. 179-192.

¶ *Centralblatt für Mineralogie*, 1904, pp. 40-49.

\*\* *Das Mineralreich*, Stuttgart, F. Lehmann, 1904.

†† *Edelsteinkunde*, Leipzig, C. H. Tauchnitz.

‡‡ *Precious Stones*, London, Griffin, 1904.

§§ *American Journal of Science*, vol. xvii. pp. 241-242.

An unusual pseudomorph of limonite after quartz is described by E. Döll.\*

E. Holm† has investigated the magnetic properties of various minerals contained in Swedish iron ores.

**Iron Ore in West Cumberland.**—In a detailed account of the Institute's meeting in Barrow-in-Furness, J. de Lazurtegui‡ gives an exhaustive description of the iron ore deposits of West Cumberland.

A. Weiskopf§ gives a detailed account of the Hodbarrow iron mine in West Cumberland visited by him on the occasion of the meeting of the Iron and Steel Institute at Barrow-in-Furness. The paper is illustrated by a geological map of the district and by drawings of the sea-wall.

**Ironstone in North Staffordshire.**—The second part of the paper by John Cadman|| on the occurrence, mode of working, and treatment of the ironstones found in the North Staffordshire coalfield has now appeared. Some additions to the bibliography are made, and various historical notes on the clay-band ores are given. Typical sections with some notes on them follow, and also a table of analyses showing a percentage of iron ranging from 20 to 35. Then comes a description of the long-wall workings, and an illustrated account of the method adopted for calcining the ore.

**Iron Ore in Austria.**—Numerous small deposits of hæmatite have long been known in the neighbourhood of Klein Zell in Lower Austria. They occur in Triassic limestone. The explorations made in connection with them have proved the existence of a 26-foot vein of limonite of a very pure quality. It contains but little sulphur and phosphorus, and its iron contents amount to 43 per cent., and by calcination can be raised to 59 per cent. A railway is projected that will afford ready transport facilities for mining in the neighbourhood.¶

An elaborate monograph on the mineral deposits of the Archæan and Devonian Islands of West Moravia has been published by F. Kretsch-

\* *Verhandlungen der k.k. Geologischen Reichsanstalt*, 1903, pp. 316-317.

† *Jerkontorets Annaler*, vol. lviii. pp. 363-380.

‡ *La reunion del Instituto del Hierro y del Acero*, Bilbao, 1903.

§ *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 149-152.

|| *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 106-120; see also *Journal of the Iron and Steel Institute*, 1902, No. I. p. 433.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 13.

mer.\* Much information is given regarding the Quittein iron ore deposit.

By the construction of a new railway, the opening of the magnetite mines at Hammerstadt-Vlastejovic in Bohemia is rendered possible. The deposit, according to A. Irmeler,† is enclosed in diorite, and is about 750 yards in length. The magnetite is mixed with garnet and hornblende, and averages 50 to 52 per cent. of iron.

**Iron Ore in Bosnia.**—On the occasion of the ninth International Geological Congress, the Government issued a geological guide to Bosnia and the Herzegovina by F. Katzer.‡ It covers 280 pages, and contains an account of the geology of the country, with eight maps. Details are given of the iron ore deposits. The iron ore bed at Vares is of Triassic age, and consists of clay iron ore and hæmatite. It produces 44,000 tons of pig iron annually.

**Iron Ore in France.**—M. Etienne§ gives the following analyses of iron ore from the Calvados:—

	Assy.	Sassy.	St. Quentin.	Perrières.
Silica . . . . .	20.00	22.55	32.51	13.72
Phosphorus . . . . .	0.05	0.02	0.02	0.07
Alumina . . . . .	3.18	2.09	3.58	1.72
Iron . . . . .	49.48	49.28	39.78	52.28
Lime . . . . .	1.46	1.18	1.14	3.48

A description has been published of the Batère-las-Indis iron ore mines in the Pyrenees.||

**Iron Ore in Germany.**—The hæmatite deposit at Lauterberg in the Harz is described by K. Ermisch.¶ The average composition of the ore produced at the Kuollen mine is as follows:—

Fe <sub>2</sub> O <sub>3</sub> .	Insol. Residue.	Al <sub>2</sub> O <sub>3</sub> .	MnO.	CaO.	MgO.	Loss.
60 to 70	18 to 20	5	0.2	2	1	4

Plans and sections of the mine are given.

C. Chelius \*\* describes the iron ore deposits at Mücke and other locali-

\* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. lii. pp. 353-494, with maps.

† *Hornické a hutnické listy*, 1902, pp. 22-23; *Geologisches Centralblatt*, vol. iv. p. 362

‡ *Geologischer Führer durch Bosnien*, Sarajevo, 1903.

§ *Annales des Mines*, vol. iv. p. 550.

|| *Banyaszati és Kohászati Lapok*, vol. xxxvii. pp. 182-183.

¶ *Zeitschrift für praktische Geologie*, vol. xii. pp. 160-172.

\*\* *Ibid.*, p. 53.

ties in Upper Hessen. The ore is brown hæmatite containing 43 to 46 per cent. of iron, poor in phosphorus and manganese.

A. Schmidt\* has published a pocket-book describing the minerals occurring in the Fichtelgebirge and the Steinwald. Historical notices are given of the iron and manganese mines formerly worked.

The red hæmatite beds in the Devonian rocks of north-west Germany occur in association with diabase, and have been thought to have been derived from the weathering of that rock. E. Harbort,† however, shows that they are primary deposits, deposited simultaneously with the limestone.

G. Berg ‡ describes the magnetite deposit of Schmiedeberg in the Riesengebirge.

In connection with the canalisation of the river Lahn, Germany, details are given as to the iron ore deposits in its side valleys.§ These show the following figures:—

	Mined or Opened Out.	Not yet Opened Out.
	Metric Tons.	Metric Tons.
Red iron ore . . . . .	5,520,000	23,400,000
Bog iron ore . . . . .	3,580,000	600,000
Brown iron ore . . . . .	25,150,000	17,000,000
Total . . . . .	34,250,000	41,000,000
Approximate value . . . . .	£13,000,000	£18,000,000

In addition, 50,000 tons of brown coal are opened out, and another 15,000,000 tons are estimated to exist. . About 60 per cent. of the first mining costs is represented by wages.

To the north of the town of Wesel, on the lower Rhine, borings have shown the presence of extensive beds of iron ore.|| For a considerable time past various undertakings have been in existence for the exploitation of the beds of coal and of potassium salts found there amid the still lower lying coal-seams. Not long ago one of the boreholes that was being put down in the vicinity of Bislich struck Lias beds quite unexpectedly at a depth of about 270 yards, and in these, at a depth of some 510 yards, a bed of clay ironstone was met with which is nearly 33 feet in thickness. This strike has led to considerable activity in this district, 20 boreholes being in process of being put down. It is thought that these newly discovered deposits will be of much importance to the iron industry of the lower Rhine.

\* *Die Mineralien des Fichtelgebirge*, Bayreuth, 84 pp., price 1s. 6d.

† *Geologisches Centralblatt*, vol. iv. pp. 620-622.

‡ *Jahrbuch d. königl. Preuss. Geol. Landesanstalt*, vol. xxiii. pp. 201-266, with ten illustrations and geological map.

§ *Stuhl und Eisen*, vol. xxiii. pp. 1242-1244.

|| *Ibid.*, vol. xxiii. p. 1926.

B. Schulz-Briesen\* describes the minette bed encountered in the Bislich borehole. This seam, which was unexpectedly met with at a depth of 1580 feet, contains at least 3,000,000 tons of workable ore, with 30.36 to 32.29 per cent. of iron and 0.5 per cent. of phosphorus.

**Iron Ore in Luxemburg.**—J. W. Pearse† describes the iron ore deposits of Luxemburg, giving shortly an account of the various localities where the ore is worked. In the discussion, Bennett H. Brough referred to a recent paper by W. Kohlmann in which the average compositions are given as—

	Iron.	Silica.	Alumina.	Lime.
Brown ore . . .	38 to 42	14 to 15	8	3 to 5
Grey ore . . .	30 to 32	8 to 9	4 to 5	16 to 18

Minette iron ores contain the following percentages :—

Silica.	Iron.	Lime.
2.3 to 25.3	11.4 to 41.5	5.6 to 41.3

the sum of these three constituents always amounting to between 55 and 59 per cent., and averaging about 57.

**Iron Ore in Norway.**—The paper, read before the Congress of Applied Chemistry by J. H. L. Vogt‡ on the exports of iron ore from Norway, has been published in full.§ The Gellivare, Kiirunavaara, and Luossavaara deposits in Sweden and the Dunderland deposits in Norway are described, and an optimistic view of the future of the Norwegian iron ore export trade is taken. A. Weiskopf|| expresses disagreement with Vogt's conclusions.

G. Henriksen¶ has published in pamphlet form an account of the iron ore deposits in Sydvaranger. The ore, of which there is some 100 million tons available, is similar to that of Dunderland.

**Iron Ore in Russia.**—The iron ore of Troitsk in the Northern Ural is described by L. Duparc\*\* and L. Mrazec.

In another paper the same authors †† describe the brown iron ore deposits of the mining districts of Kisel in the Ural. The iron ores were mined on a large scale more than a hundred years ago, most of

\* Glückauf, vol. xl. pp. 361-370.

† Transactions of the Institution of Mining Engineers, vol. xxv. pp. 580-591.

‡ Journal of the Iron and Steel Institute, 1903, No. I. pp. 500, 529.

§ Zeitschrift für praktische Geologie, vol. xii. pp. 1-7.

|| Ibid., pp. 94-96.

¶ "The Iron Ore Deposits of Sydvaranger," Christiania, 1904.

\*\* Comptes Rendus, vol. cxxxvi. pp. 1409-1411.

†† Oesterreichische Zeitschrift für Berg- und Hüttenwesen, vol. li. pp. 711-715, 735-740, with ten illustrations.



the undertakings then commenced being now in the possession of the Prince Abamelek-Lazarev. The ores are found in a well-wooded district from four to six miles from the town of Kisel, where they are smelted. Three kinds of the iron ores are distinguished commercially—"heavy," "light," and "porous"; the latter is very full of small cellular spaces. All possess spheroidal structure, and they contain some clay. Chemically they differ very little from one another, the iron contents varying from 46 to 57, the average being from 51 to 52. Phosphorus or sulphur does not exceed 0.12 per cent., but silica is usually present in quantity amounting to about 9 or 10 per cent. Siderite is never met with. The ore occurs in the form of a series of lenses or, but more rarely, bed-like deposits, narrowing out at the ends and arranged like the links of a chain, the ore bodies never being entirely separated from each other except by very short intervals. The average width of the ore bodies may be estimated at about 130 feet, but in those deposits more closely resembling beds it appears to be nearly five times as great, with a maximum thickness of some 40 feet. The thickness of the ore varies as a rule between 3 and 50 feet. The method of mining is described and the various mines are named. About 100 million poods of ore have so far been mined since the deposit began to be mined, and about 180 million poods, or less than 3,000,000 tons, are still available for mining. The ores are probably of surface origin, the limestone having acted as a precipitant on ferruginous surface waters.

**Iron Ore in Finland.**—It is reported that an extensive deposit of iron ore has been discovered in the government of Wiborg on the shore of Lake Ladoga.\*

**Iron Ore in Spain.**—E. Mackay-Heriot† gives a general and illustrated account of the Bilbao iron ore mines, dealing with their history, geological condition, nature of the deposits, and ore.

Deposits of iron ore have recently been discovered at Almohaja in the South Aragonian province of Teruel, nine miles from the Santa Eulalia station on the Central Aragonian railway. The ore is hæmatite, with 54.34 per cent. of iron and 1.95 of manganese.‡

According to Teichgräber,§ the mountains of the province of Lugo,

\* *Chemische Zeitschrift*, vol. iii. p. 308.

† *Engineering and Mining Journal*, vol. lxxvi. pp. 510-512.

‡ *Engineering*, vol. lxxvi. p. 571.

§ *Stahl und Eisen*, vol. xxiv. pp. 332-334.

in the north-east of Galicia, are composed almost entirely of palæozoic slates. This slate varies in colour and appearance and in its silica contents, passing in places into quartzite. The strike is almost without exception from W.N.W. to E.S.E., and the dip is to the south. A number of ferruginous springs occur in these mountains, betraying their contents by a deposition of ochre. Iron ore crops out in many places, and was mined and smelted at numerous small works down to the middle of the past century. The extent of these old workings leads at first to the assumption that there must be extensive beds of iron ore. The author shows, however, that this assumption is erroneous. There appear to be numerous small deposits of iron ore of irregular shape, produced probably by deposition from mineral springs. Despite the fact that the various deposits have been claimed to contain many millions of tons of ore, the author is of opinion that this is quite inaccurate, and that these deposits are of no great commercial value.

Several iron ore mines in the North-East Pyrenees raised in 1901 78,000 tons of iron ore. Another group raised 40,000 tons. The ores are chiefly spathic carbonates, which have been converted into brown iron ore near the surface. The brown ore contains about 51 per cent. of iron and 4 per cent. of manganese. Various mines and smelting works are briefly mentioned, and in some cases the ore reserves are believed to be considerable.\*

**Iron Ore in Sweden.**—The iron ore deposits of Lapland are described by W. Petersson,† who states that, on behalf of the Government, Svenonius and himself paid a special visit in 1900 to the iron ore deposits of Norbotten, which had become known since 1875. They were to inspect these as thoroughly as was possible, the ore region extending from the Gellivare district in the south to the Torne Marsh in the north, the width from east to west being about the same, with Kiirunavaara as a central point. The Gellivare-Ofoten railway cuts across it. It was found that the iron ore bearing rocks were chiefly syenite porphyry and syenite granulite, with basic eruptive rocks, such as gabbro, diabase, &c., occupying a subordinate position. On the other hand, granulite (Hällefinta-gneiss, Eurite), which is of a particularly ore-bearing character in Central Sweden, is entirely absent. In the

\* *Mémorial de la Loire*; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. p. 692.

† *Wermländska Annaler*; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 742-743.

syenite porphyry the ore occasionally occurs in large masses, as well as in other forms. Ore deposits in this rock include those of Kiirunavaara, Luossavaara, and others which the author mentions. The ore deposits in the syenite granulite more closely resemble those of Central Sweden. They are elongated lenticular deposits, agreeing in strike and dip with the enclosing rock. The chief deposits of this kind are those of Svappavaara and Leveäniemi. In the basic eruptive rocks sometimes small magnetite deposits of irregular shape are met with, but they do not appear to be of any practical importance in the region now under consideration. To these belong the deposits at Tjabrak and Tjavelk. In many instances the surface covering of earth prevented any accurate geological examination. In addition to the ore-bearing rocks already named, granite in many forms is widespread, especially in the south-eastern section of the region, and clay slates, sandstones, and conglomerates are also met with, though not to any great extent. Rocks which belong to the Cambrian-Silurian horizon were found in the north-western portion of the region traversed. A large proportion of the ore deposits seen were of little or no practical importance. In addition to the well-known deposits of Gellivare, Kiirunavaara, and Luossavaara, with which the author and his colleague were not required to deal, the more important ore deposits seen proved to be those of Svappavaara, Leveäniemi, Ekströmsberg, Tuollavaara, and Mertainen.

The Svappavaara ores are red iron ores and magnetites, both with apatite and calcspar in varying and sometimes considerable quantities. The iron contents varies from 43 to 70 per cent., the phosphorus from 0.1 to 3.1, the calcium carbonate from 0 to 20.7 per cent., the sulphur from 0.012 to 0.060, and the titanitic acid from 0.09 to 0.45 per cent. The ore deposit covers 50,000 square metres, about 40 per cent. of the ore being magnetite.

The Leveäniemi deposit is rather over a mile distant from that just described, and was not discovered until the autumn of 1897. At the time of the author's visit, 23 boreholes had been put down in various places by means of the diamond drill. Most of these had struck either red iron ore or magnetite. Some of this resembled that of the other deposit in being rich in apatite and calcspar, while some only contained from 0.008 to 0.040 per cent. of phosphorus, and was very high in iron contents. Three boreholes were in solid ore for depths respectively of 137, 144, and 189 feet. This would point to this ore deposit being of great importance, taken in connection with the magnetic observations also pointing in this direction.

The Tuollavaara deposit was also discovered in 1897, and has an area of about 10,000 square metres. It contains rich magnetites low in phosphorus. The Ekströmsberg deposit has long been known, but was forgotten, and not rediscovered until 1895. It contains red iron ores and magnetites high in phosphorus, the area of the deposits being estimated at from 40,000 to 50,000 square metres. The area of the Mertainen deposit is considerable, but it appears to be of less commercial importance. The ores are very low in phosphorus, usually less than 0.05, while the iron contents vary from 60 to 70 per cent. In addition to the above-named deposits, 39 others were also seen, and it is possible that considerable deposits of red iron ore which the magnetic needle has failed to locate may yet be found. Indeed, the author thinks this probable for reasons that he gives.

The Lapland iron ore deposits have now passed definitely into the control of the Grängesberg Ore Transportation Company, which has by purchase acquired more than 90 per cent. of the Gellivare, Luossavaara, and Kiirunavaara companies. It is stated that although this company bears a Swedish name it is partly composed of British and German capitalists. The quantity of iron ore exported from January to July from Narvik has risen to some 441,000 tons, about 270,000 tons of which went to Germany and 82,000 tons to the United Kingdom.

Swedish ironmasters have acquired the Tuollavaara deposit of iron ore, near Kiiruna. This contains about 68 per cent. of iron and some 0.010 per cent. of phosphorus. This ore is to be exported from Narvik to Gothenburg, thence by ship to the Wener lake and on to Wener-Shamn, and from that place it will be distributed by rail to eight iron-works in that district.\*

Some further information is given as to the iron ore resources of Sweden.† The Gellivare-Malmfält Company estimates its iron ore deposits at between 50 and 60 million tons. The Gellivare mines are the largest producers in Sweden. Of the total output of iron ore in Sweden in 1900, amounting to 2,607,925 tons, 954,020 tons were produced by the Gellivare mines, while in 1901 and 1902 their outputs were respectively as follows: 1,076,020 tons and 982,321 tons, the total outputs for Sweden in this period being respectively 2,607,925 tons and 2,793,566 tons.

The Luossavaara-Kiirunavaara mines are believed to contain in all down to a depth of 109 yards, 635,000,000 tons. The iron contents

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 143.

† *Stahl und Eisen*, vol. xxiii. p. 1366.

amounts to 60 per cent. and upwards, and as the phosphorus contents are high they are suitable for the basic Bessemer process. In 1901 only 119,620 tons of ore was raised, but the opening of the Ofoten railway and the harbour at Narvik will cause a rapid development of these ore deposits. In 1902 the output had already risen to 232,327 tons.

C. S. Osborn \* describes the extent, quality, and development of the iron ore deposits in Swedish Lapland.

A description of the Norrland iron ore fields has been published.†

Juan Hereza ‡ gives a summary of L. de Launay's description of the Kiirunavaara mines in Sweden, and compares them with the iron ore deposits of Huelva.

**Iron Ore in Switzerland.**—The iron and manganese ore deposits of Switzerland are described by A. Wencelius.§ Particulars are given of the Gonzen mines in the Sargans district and of the Haslithal mines in the Upper Aare Valley.

It is proposed to make use of some 65,000 horse-power, available by the utilisation of water power near Meiringen in Switzerland. A. Heim || estimates that some millions of tons of iron ore are capable of being mined to commercial advantage in that district, the following being analyses made at the Zürich Polytechnic :—

	Ore from the Gental.	Ore from the Urbachtal.	Hæmatite.
	Per Cent.	Per Cent.	Per Cent.
Silica . . . . .	13·20	15·85	9·68
Ferric oxide . . . . .	27·54	40·48	77·43
Ferrous oxide . . . . .	33·04	7·25	3·15
Manganese oxide . . . . .	...	traces	traces
Alumina . . . . .	8·30	10·15	0·97
Lime . . . . .	0·91	8·25	3·49
Magnesia . . . . .	2·19	3·45	traces
Phosphoric acid . . . . .	0·19	1·19	0·05
Sulphuric acid . . . . .	...	1·05	2·44
Sulphur . . . . .	0·05	...	...
Carbonic acid . . . . .	7·25	6·82	2·98
Water . . . . .	6·46	3·44	...
Alkalies by difference . . . . .	0·87	2·07	...
Totals . . . . .	100·00	100·00	100·19

\* Paper read before the Lake Superior Mining Institute, August 1903; *Mines and Minerals*, vol. xxiv. pp. 111-113.

† *Afärsvärlden*, 1903, No. 50.

‡ *Revista Minera*, vol. lv. pp. 73-75.

§ *Berg- und Hüttenmännische Zeitung*, vol. lxii. pp. 541-545, 629-631.

|| *Stahl und Eisen*, vol. xxiii. p. 1361.

**Iron Ore in India.**—During the survey of the Dhar forest, the rich iron ores that form fault breccias received attention from E. Vredenburg\* and L. L. Fermor. They follow lines of faulting, the richest hæmatitic deposits being found along the great fault separating the Vindhyan and Bijawar systems. Absence of fuel prevents the development of these ores.

A. Primrose† describes the iron ore deposits of the Bangalore, Kolar, Tumkur, and Mysore districts. Incidentally he gives an account of the method of smelting carried on in the Tumkur district. Native iron smelting is gradually becoming a thing of the past.

V. S. Sambasiva Iyer‡ describes the iron ores smelted in the districts of Chitaldroog and Shimoga.

**Iron Ore in Canada.**—The genesis of the Animikie iron range is discussed by F. Hille.§ He shows that there are in Canada the same iron-bearing rocks as exist in the Lake Superior iron ranges. The conditions for the formation of the iron ore deposits are identical with those elsewhere, and there is consequently no reason why there should not exist as large deposits as in the Mesabi district.

In a paper on the geology of the northern portion of the Boisdale hills anticline, in Cape Breton island, S. H. Boright|| notes the occurrence of hæmatite of good quality on Long Island.

A. B. Willmott¶ deals with the exploration of the Ontario iron ranges, and refers to the geological similarity between certain belts in Ontario and those found south of Lake Superior. It has often been stated that Ontario and Quebec abounded in iron ore of the first quality, yet the Hamilton, Sault, and Midland furnaces have only one large producing mine to draw from. Probably the lack of known ore bodies is owing to the fact that they have not been properly sought. The best method of interpreting and verifying the numerous surface indications is discussed, and the Josephine and Frances mines are given as instances where surface indications were slight, but where deep drilling had met with entire success. During the past two years some intelligent and systematic work has been done on the Steep Rock, Animikie, Michipicoten and Hutton ranges, and in most cases good ore bodies had been discovered.

\* *General Report of the Geological Survey of India*, 1903, p. 14.

† *Mysore Geological Department Records*, vol. iii. pp. 210-215.

‡ *Ibid.*, pp. 240-246.

§ *Journal of the Canadian Mining Institute*, vol. vi. pp. 245-287.

|| *Ibid.*, pp. 411-433.

¶ Paper read before the Canadian Mining Institute, March 1904.

**Iron Ore in New South Wales.**—Particulars of the occurrence of iron ore in New South Wales are recorded in the official year-book of the colony.\*

E. F. Pittman † reports on the so-called ironstone deposits in County Cumberland. They are really ferruginous sandstones.

**Iron Ore in Victoria.**—J. W. Gregory ‡ has furnished a report on the iron ore deposits recently found at Mirboo North, in the Gippsland district. Several samples showed the following composition: Silica, 2·75; titanic oxide, 1·00; ferric oxide, 77·14; ferrous oxide, 1·80; alumina, 3·70; lime, nil; magnesia, nil; sulphur, 0·07; phosphorus, 0·01; water (at 100° C.), 2·22; water (ignition), 11·30; total, 99·90.

**Iron Ore in Western Australia.**—The iron ore deposits in Western Australia are broadly divided according to a government report,§ into two main divisions—(a) the ores associated with the crystalline schists and other allied rocks; and (b) the superficial deposits of limonite (laterite ore), which occupy extensive areas in many and widely separated portions of the State, and the soft porous deposits of hydrated oxide of iron (bog ore) of comparatively recent origin. The important ores associated with the crystalline schists are developed most extensively in the watershed of the Murchison River, more especially between 25 degrees and 28 degrees of south latitude, and 116 degrees and 119 degrees east longitude. The most important localities are named. No detailed survey has as yet been made, but it is stated that a 70-foot layer of hæmatite occurs at Mount Hale.

**Iron Ore in the United States.**—Reports on a number of the iron ore fields of the country have been issued by the United States Geological Survey. Amongst these are papers by J. S. Diller ¶ on the iron ores of the Redding quadrangle, California; by C. W. Hayes and E. C. Eckel ¶¶ on the iron ores of the Cartersville district, Georgia; by A. Keith \*\* on the iron ore deposits of the Cranberry district, North Carolina; and by C. K. Leith †† on recent geological work in the Lake

\* *The Year-Book of New South Wales*, London, 1904, p. 133.

† *Annual Report of the Department of Mines*, New South Wales, 1902, p. 128.

‡ *Iron and Coal Trades Review*, vol. lxvii. p. 1080.

§ *Ibid.*, pp. 1007-1008.

¶ *United States Geological Survey, Bulletin* No. 213, pp. 219-220.

¶¶ *Ibid.*, pp. 233-242.

\*\* *Ibid.*, pp. 243-246.

†† *Ibid.*, pp. 247-250.

Superior iron district. A list of previous publications by the Survey on iron ores is also given.\*

A catalogue and index of the publications of the United States Geological Survey, 1901 to 1903, has been compiled by P. C. Warman.† It contains numerous references to the occurrence of iron ore in the United States.

**Iron Ore in the Lake Superior District.**—J. E. Spurr,‡ dealing with the original source of the Lake Superior iron ores, meets the objections of Van Hise and Leith to giving the name "glaucosite" to the green ferrous silicate which all admit was the original source of the Mesabi ores, by comparing the material with various undoubted glauconites. Though the Mesabi silicate is low in potash, it is nearer in this regard to the Australian and French glauconites than they are to that from Grodno, Russia. The author shows that the surface, at the time of deposition of the Mesabi silicate, consisted of rocks very low in potash, and he concludes that the Mesabi silicate is entitled to the name glauconite.

According to W. S. Bayley § the Menominee district forms a narrow tongue with an area of 112 square miles on the Michigan side of the Menominee River. It has been an important factor in the iron ore production since 1897. The district is bordered by areas of Archean schists and granites. The Huronian sediments of the district, in which the ore bodies occur, lie in a trough between these older rocks. Structurally this trough is a syncline composed of several important anticlines and synclines. The Huronian rocks are divided into two series called the Upper and Lower Menominee, which are separated from each other by an unconformity. The Lower Menominee series comprises 1050 to 1250 feet of quartzites and conglomerates, with 1000 to 1500 feet of dolomites. The Upper Menominee series comprises the Vulcan formation, 650 feet thick, and the Hanbury slate. The Vulcan formation includes three members: the iron-bearing Traders members, consisting largely of detrital ores and jaspilites, but having basal layers of slate, quartzite, and conglomerate; the Brier member, composed of ferruginous and siliceous slates; and the Curry member, consisting of quartzites, ferruginous quartzose slates, jaspilites, and ores.

\* *United States Geological Survey, Bulletin No. 213, p. 256.*

† *Ibid.*, No. 215, p. 234.

‡ *American Geologist*, vol. xxix. pp. 345-349.

§ *Monographs of the United States Geological Survey*, vol. xlv. 513 pages.



The larger ore deposits all rest upon relatively impervious foundations, which are in such a position as to constitute pitching troughs. The ores of this district, like those of the Gogebic and Marquette districts, were concentrated by descending waters flowing in definite channels, and the general processes involved were the same as those worked out by Van Hise for these other districts.

J. Morgan Clements\* has published a monograph, covering 463 pages, upon the Vermilion iron-bearing district of Minnesota. This district resembles the other iron-bearing districts of the Lake Superior region in that the rocks are of very great geological age. From a topographic standpoint it is divisible into four areas, the geological features of which are dealt with in the opening chapters. The iron formation is widely distributed in the western part of the district, but is practically wanting in the eastern half. It consists of siliceous rocks, largely white cherts, with red jasper and carbonate-bearing chert, grünerite-magnetite schist, hæmatite, magnetite, and small quantities of pyrites. The hæmatite occurs in certain places in masses of variable size, which constitute the ore deposits. These rocks are clearly of sedimentary origin, and are presumed to have been derived from rocks that were largely carbonate-bearing, ferruginous cherts. The first statements regarding the occurrence of iron ore were published in 1850, but systematic development did not begin until 1884. The ores are extremely hard, massive, blue hæmatites. In the Chandler mine the ores have been brecciated, but the fragments of the breccia are still the blue hæmatite, averaging 63·7 per cent. iron, 0·05 phosphorus, 4·78 silica, and 5·5 per cent. water.

The mode of origin assigned to the ore bodies is the same in general as that given for the other districts, and which has been described in detail by Van Hise in the monograph of the Penokee district. The monograph is well illustrated and is accompanied by an atlas giving detailed maps of the area.

In a paper read before the Verein Deutscher Eisenhüttenleute, H. Macco† describes a visit he had paid to ironworks in the United States and to the iron ore fields, especial attention being devoted to the iron ore deposits of the Lake Superior region, especially the Mesabi field, the transportation of the ore from this district to the nearest port, lake transport, and the subsequent railway journey to Pittsburg. The output of iron ore in the whole of the Lake Superior

\* *Monographs of the United States Geological Survey*, vol. xlv. 463 pages.

† *Stahl und Eisen*, vol. xxiv. pp. 69-81, with six illustrations.

district in 1902 amounted to over 28 million tons, of which 13·5 millions was produced in the Mesabi portion of that region. This latter field has only been energetically worked for the past ten years. The ore is thought to be of aqueous origin, leached from other ferruginous rocks and redeposited. The result has been that the ore varies very greatly in its iron contents, which range from 40 to 68 per cent. The ore reserves of the Mesabi district are estimated, as the result of a very complete system of boreholes, at some 500 million tons. At first purchasers required that the ore should contain from 62 to 68 per cent. of iron, with the result that large quantities of the poorer grades were left, and are probably no longer commercially available.

In Germany, the author observes, the iron ore smelted contains as a rule from 25 to 45 per cent. of iron. High percentage Mesabi ore proving to exist in less quantity than had been anticipated, the average iron contents gradually became reduced to 58 per cent.; and during the past summer that smelted at the works of the United States Steel Corporation has averaged only 52 to 54 per cent. This is obtained by admixture of high and low percentage ores. In addition to the iron contents the percentage of moisture present is of great importance from the transportation point of view. It averages, in the Mesabi district, from 8 to 10, but rises exceptionally to 15·5. It has therefore been suggested that the ore should be artificially dried at the mines. At present the soft brown ores are those chiefly mined. The hard ores are broken down in mills to pieces, none of which exceed 6 inches in size. About half the ore is won open-cast. The method of mining is described, and then the author proceeds to discuss the Marquette district. Here it is chiefly deep mining that is practised. The author next deals with the transport of the ore to Lake Superior. This is effected by three lines of railway, particulars being given as to these, the methods of transport that they adopt, and the results achieved, comparison being made with the Prussian railway system. The water transport is subsequently dealt with, and the methods in use for loading and discharging cargo are described.

In another memoir A. Macco \* gives a detailed description of the Lake Superior iron ore deposits.

**Iron Ore in New York.**—W. O. Crosby † gives a geological history of the hæmatite iron ores of the Antwerp and Fowler Belt

\* *Zeitschrift für praktische Geologie*, vol. xii. pp. 48-53.

† *American Geologist*, vol. xxix. pp. 233-242.

in New York, and discusses the field relations and probable genesis of the red hæmatite ores of the western Adirondacks, in Jefferson and St. Lawrence counties. It is concluded that they originated through the alteration of sulphides which had been magmatically concentrated along the border of a dyke. The ore-body of the Sterling mine is in a dyke, 50 feet or more in width, of some highly altered basic rock, possibly diabase; the ore was originally a magmatic segregation of this rock, chiefly in the form of sulphides, which have consequently suffered more or less complete oxidation to a considerable depth, the ore being now virtually a gossan; the dyke is probably continuous for the entire length of the belt of the mines, although absolute continuity is by no means essential to the hypothesis. This dyke is bordered by granite on the south-east and by crystalline limestone on the north-west. In earlier work on these ore-deposits C. H. Smyth decided that the chloritic dyke rock was merely a highly altered phase of the granite.

**Iron Ore in North Carolina.**—According to A. Keith,\* the principal ores of the Cranberry District, North Carolina-Tennessee, are magnetites, which occur as a series of large lenses in granite. They are regarded as replacements of some basic intrusive, the process of ore-deposition having taken place after the deformation which made the granite schistose. The ores carry 42 to 46 per cent. metallic iron; but the gangue consists largely of pyroxene, hornblende, and epidote, so that cleaning and concentration are rather difficult.

**Iron Ore in Pennsylvania.**—T. C. Hopkins† discusses the origin and relations of the numerous and extensive limonite deposits occurring in eastern and central Pennsylvania. These ores are associated with the Cambro-Silurian limestones and slates, and are part of a series of similar deposits which extend from Vermont into Alabama, following the Great Valley. The ores lie in irregular pocket-like deposits in depressions in the limestone or on an impervious basement of slate or clay. It is concluded that the original source of this iron was the limestones and slates with which the ore-deposits are now associated. He considers that the segregation of this diffused iron into ore lumps was brought about by the action of meteoric waters, aided by organic matter; and that the iron taken

\* *United States Geological Survey, Bulletin No. 213, pp. 243-246.*

† *Bulletin of the Geological Society of America, vol. ii. pp. 475-502.*

into solution by these waters is precipitated largely in the upper beds of the limestone, in cavities or seams, or along the contact of the limestone and slate. As the limestones are dissolved, the masses of ore thus formed settle down with the residual clay. An average of 29 analyses shows 62.11 per cent. ferric oxide, 2.85 per cent. manganese oxide, 2.39 per cent. alumina, 18.97 per cent. silica, 11.62 per cent. water; with 1.10 per cent. phosphoric anhydride and 0.06 per cent. sulphur.

**Iron Ore in Tennessee.**—Iron ores occur in Maury and Hickman counties, Tennessee, the largest deposit being at Nunelly, where a pockety mass of hæmatite is found in red clay.\*

**Iron Ore in Washington.**—According to S. Shedd, † deposits of magnetite, hæmatite, limonite, and magnetite mixed with hæmatite occur in the State of Washington, chiefly in Skagit, King, Kittitas, Stevens and Mason counties.

Along the Skagit river from Hamilton to Marblemount, Skagit county, a series of magnetite-hæmatite bodies occur. They are probably separate lenses, though they have a certain parallelism of outcrop. The ores are dark coloured, massive, and more or less magnetic. They carry from 29.11 to 46.60 per cent. metallic iron, 7.31 to 14.28 per cent. manganese oxide, and 0.25 to 2.43 per cent. phosphorus pentoxide. A certain amount of development work has been done in this district, and several coal beds of good grade occur in the vicinity of Hamilton. In King county deposits of magnetite occur near Snoqualmie Pass, being associated usually with beds of crystalline limestone. These ores range from 62.45 to 68.54 per cent. metallic iron, 1.89 to 5.78 per cent. silica, with very low sulphur and only traces of phosphorus. Magnetite-hæmatite deposits occur in the Clealum district, Kittitas county. While high in metallic iron (46.24 to 57.12 per cent.), the Clealum ores carry 5.54 to 15.58 per cent. silica and 1.92 to 25.95 per cent. alumina.

Near Colville and Valley, in Stevens county, hæmatite and limonite bodies occur in limestone and porphyry. These ores carry from 50.48 to 68.10 per cent. metallic iron, 0.36 to 0.72 per cent. phosphorus pentoxide, and 0.21 to 0.38 per cent. sulphur. Of all the

\* *United States Geological Survey* (Columbia Folio No. 95), Washington, 1903, pp. 24 (price 25 cents).

† "The Iron Ores of Washington," *Washington Geological Survey*, vol. i. pp. 215-256.

deposits described in this report, few have been developed sufficiently to permit any estimate of size being made. Most of them are, moreover, situated far from existing railroads.

**Iron Ore in Wisconsin.**—An account of the recent developments in the Baraboo iron ore district, Sauk county, Wisconsin, has appeared.\* A shaft at the Illinois mine has been sunk to a depth of 400 feet, and levels driven in hæmatite ore ranging from 50 to 65 per cent. of iron. A number of analyses are given of ore at this and the Sauk mine. In all analyses the phosphorus does not exceed 0·07 per cent. This district is also described by O. Rohn.†

**Iron Ore in Wyoming.**—According to W. S. T. Smith,‡ the iron ores of the Hartville district of Laramie county, Wyoming, occur in a series of quartzites, limestones, and schists, called the Whalen group, supposed to be Algonkian. Overlying these rocks unconformably is the Guernsey formation of Carboniferous age. The basal beds contain rounded pebbles of hæmatite, indicating that the formation of the iron ore-bodies had occurred before the Carboniferous rocks were deposited. The ores are hæmatites of two varieties. One, known as "paint ore," is soft, schistose, fine-grained, light red in colour. "Blue ore" is a harder, dark bluish-grey, more valuable variety. All the known occurrences are included in a limited area on the west side of Whalen cañon. The ore-bodies occur in both limestones and schists, being best developed along and near the contact of the two rocks. In the limestone the ore occurs in irregular, scattered pockets; in the schists, it is in the form of long lenses, varying from a few inches to 100 feet wide. The principal body is worked by the Colorado Fuel & Iron Company at Sunrise. The ore is taken out by steam shovels from an open-cut, and averages about 62 per cent. of iron,  $2\frac{1}{2}$  of silica, and practically no phosphorus or sulphur. The ore is found in pockets in Algonkian rocks near the contact of schist and limestone. It is either a soft red or hard blue grey hæmatite.

An illustration is given§ of the open workings for iron ore at the Sunrise mine, Laramie county, Wyoming. The ore is hæmatite, and occurs in pockets in carboniferous limestone over some 20 square

\* *Iron Age*, September 17, 1903, pp. 22-23.

† *Engineering and Mining Journal*, vol. lxxvi. pp. 615-617.

‡ *United States Geological Survey* (Geologic Folio No. 91), Washington, 1903, pp. 18 (price 25 cents).

§ *Iron Age*, November 26, 1903, p. 13.

miles. It contains 60 to 67 per cent. of iron, 2.5 to 5.0 of silica, and is very low in phosphorus. At present it is worked with steam shovels, but a shaft is being sunk. Other deposits also occur in the State.

**Iron Ore in Cuba.**—H. Souder \* gives an account of the mineral deposits of Santiago, Cuba. Manganese ores are worked in the San Luis district in the Ponupo group, the Boston mines, and the Ysabelita group, the former being most important. Here pyrolusite is obtained from pockets, one of which is 30 feet wide and 30 feet in depth. Analyses show 44 to 56 per cent. of metallic manganese and 0.03 to 0.07 of phosphorus. Iron ore in the form of magnetite and hæmatite is found over a belt 18 miles long between Sevilla and Sigua on the east of Santiago, and four groups of mines are being worked. These are the Juragua, Spanish-American, Berraco, and Sigua groups. Some maps and plans are given.

**Iron Ore on the Lower Amazon.**—F. Katzer † states that iron and manganese ores are widely distributed in the region of the Lower Amazon. The iron ores could not be profitably mined. The manganese ores, however, are well adapted for industrial purposes. The ore is psilomelane rendered impure by admixture with sand, sometimes in association with pyrolusite. The manganese appears to have been derived from basic eruptive rocks, or from hot springs containing manganese and barytes. The proportion of baryta is usually 5 to 7 per cent.

**Iron Ore in New Caledonia.**—E. Glasser ‡ describes the iron ores that occur in large quantities in the serpentine of New Caledonia. The iron is met with concentrated in three types of deposit—(1) in masses of red hæmatite with 50 to 60 per cent. of iron; (2) in grains of hæmatite more or less hydrated with 49 to 50 per cent. of iron, and in masses of ferric hydrate with 45 to 50 per cent. of iron. The author also describes the deposits of chrome iron ore in New Caledonia.

**Manganese Ore in Austria.**—L. K. Moser § describes the occurrence of manganese ore at Kroglje, near Dolina, in Istria. One sample

\* *Transactions of the American Institute of Mining Engineers*, February 1904.

† *Geologie des unteren Amazonagebietes*; *Zeitschrift für praktische Geologie*, vol. xii. p. 57.

‡ *Annales des Mines*, vol. iv. pp. 299-392, 397-536.

§ *Verhandlungen der k.k. geologischen Reichsanstalt*, 1903, pp. 380-381.

of the ore yielded 40 per cent. of manganese, 3 to 4 per cent. of silica, 20 per cent. of lime, and 18.6 per cent. loss on ignition.

**Manganese Ore in India.**—Manganese ores are widely distributed throughout the district of the Dhar Forest, and they are the form the subject of a special report by the Geological Survey of India.\*

**Manganese Ore in the United States.**—Among the reports issued by the United States Geological Survey there are several relating to the occurrence of manganese ore. C. W. Hayes† describes the manganese ores of the Cartersville district, Georgia, and J. E. Wolff‡ describes the zinc and manganese deposits of Franklin Furnace, New Jersey.

Some particulars are given of the manganese ore deposits in Georgia and Virginia by T. L. Watson§ and C. Catlett. The phosphorus contents are not high enough to affect their value.

**Manganese Ore in Cuba.**—The manganese deposits of Santiago, Cuba, are described by A. C. Spencer.|| All the deposits of manganese worked hitherto in Cuba are in the vicinity of Santiago, the ores being mixtures of manganite, pyrolusite, braunite, and wad. The first ore shipped in 1887 was a picked lot of 50 tons, and by 1890 the output had increased to 21,810 tons. Since then the production has decreased.

**Manganese Ore in Chili.**—C. Vattier¶ further describes the mineral wealth of Chili, alluding among other things to the abundant deposits of manganese ore. No smelting works, however, exist in the country, and the development at present is therefore very limited.

**Chrome Iron Ore in India.**—The chrome iron ore deposits in the Pishin and Zhob districts in Baluchistan are described by E. Vredenburg.\*\* The chromite occurs in veins and masses in the serpentines which accompany basic intrusions of Upper Cretaceous age.

\* *Board of Trade Journal*, vol. xliv. p. 68; *Annual Report of the Geological Survey of India*, 1903, p. 14.

† *United States Geological Survey, Bulletin No. 213*, p. 232. ‡ *Ibid.*, p. 214.

§ *Transactions of the American Institute of Mining Engineers*, February 1904.

|| *United States Geological Survey, Bulletin No. 213*, pp. 251-255.

¶ *Bulletin de la Société scientifique industrielle de Marseille*, vol. xxxi. pp. 13-52.

\*\* *General Report of the Geological Survey of India*, 1903, p. 9.

**Nickel and Cobalt Ores.**—B. Neumann\* describes the occurrence of nickel ore on the Saxon-Bohemian frontier.

R. Beck† describes the nickel ore deposit of Sohland on the Spree.

In a report to the French Colonial Minister by E. Glasser‡ the mineral wealth of New Caledonia is dealt with at length. After giving a general outline of the geological formations in which the valuable mineral deposits occur, the author describes the nickeliferous ore deposits of this colony which were first discovered in 1867. Numerous veins of hydrosilicate of nickel have been discovered near Mount Dore, all of which occur in the massive peridotite, the average composition being as follows :—

Silica.	Oxide of Nickel.	Magnesia.	Moisture.
41·8	22·2	19·8	16·2

These ores began to be worked in 1874, and for a time a flourishing mining industry was carried on. In 1876 the exportation was about 8000 tons of ore annually, most of which was shipped to France. In 1879 a smelting works was established where the ores were first smelted down to crude nickel, in order to reduce the excessive cost of transport, and they continued in operation until 1885, when the Canada ores began to compete with the product of New Caledonia, by which the prosperity of the latter colony was suddenly checked. As the use of nickel gradually increased, however, the industry gradually recovered, and at the present day about 134,000 tons of ore are being mined annually. The process of winning the ore and the equipment of the mines are fully described.

The nickel ore deposits of New Caledonia are described by R. G. Leckie.§

G. M. Colvocoresses|| describes cobalt mining in New Caledonia. The ore is asbolane, a cobaltiferous manganese oxide found in serpentine, and contains 2 to 9 per cent. of cobalt oxide.

**Tungsten Ore.**—It is announced¶ that at Barrueco Pardo, in the province of Salamanca, wolfram mines are being opened up.

\* *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 177–180.

† *Zeitschrift der deutschen Geologischen Gesellschaft*, vol. lv. p. 296, with two illustrations and two plates.

‡ *Annales des Mines*, vol. iv. pp. 299–392, 397–536.

§ *Journal of the Canadian Mining Institute*, vol. vi. pp. 169–179.

|| *Engineering and Mining Journal*, vol. lxxvi. pp. 816–817.

¶ *Revista Minera*, vol. liv. p. 629.



**Molybdenite.**—J. W. Wells \* describes the occurrence, concentration, and uses of molybdenite. A bibliography, including articles dealing with the value of molybdenum in steel-making, is appended.

**Recent Researches on Meteorites.**—The distribution of meteorites over the earth is discussed by F. Berwerth.†

The catalogue of the collection of meteorites of the Field Columbian Museum in Chicago, compiled by O. C. Farrington,‡ has recently been issued. It shows that the collection has grown from the 179 falls in July 1895 to 251 falls in May 1903, and the total weight from 2099 to 2289 kilogrammes. The collection has large masses of the following: Brenham, 445 kilogrammes; Canyon Diablo, 690 kilogrammes; Long Island, 528 kilogrammes; Toluca, 177 kilogrammes.

G. W. Card§ describes the Mount Browne meteorite, an ærolite that fell in New South Wales on July 17, 1902, and the Mount Dyring meteorite, another ærolite recently found by an aboriginal. These two meteorites, illustrations of which are given, are in the Sydney Museum.

J. C. H. Mingaye|| has analysed a small sample from a meteorite found in 1899 in a sluicing claim in heavy boulder-wash at Bendock, Victoria, New South Wales. It belongs to the class of mixed meteorites or siderolites, which contain metallic iron and various silicates in their composition. The metallic portion consisted mainly of iron, iron oxide, and nickel, the chemical composition being as follows:—

SiO <sub>2</sub> .	Fe.	Ni.	Co.	Cu.	MgO.	S.	P.	O.
1·54	78·288	7·814	0·526	trace	1·874	0·461	0·184	9·313

The specific gravity was 5·839. The non-metallic portion, when treated with hydrochloric acid, gave a copious evolution of sulphuretted hydrogen. 96·4 per cent. of the substance was found to be soluble in hydrochloric acid, and analysis showed that it was essentially a silicate of magnesia and iron, with iron sulphide.

A. Liversidge¶ describes the Narraburra meteorite, weighing over 70

\* *Journal of the Canadian Mining Institute*, vol. vi. pp. 47–65.

† *Tschermaks Mineralogische Mitteilungen*, vol. xxii. pp. 189–193.

‡ *American Journal of Science*, vol. xvii. p. 329.

§ *Records of the Geological Survey of New South Wales*, vol. vii. p. 218.

|| *Report of the Ninth Meeting of the Australasian Association for the Advancement of Science*, 1902, pp. 162–164.

¶ Paper read before the Royal Society of New South Wales, September 2, 1903; *Chemical News*, vol. lxxxviii. p. 233.

lbs., which was discovered in 1855 on the Yeo Yeo Creek, twelve miles east of Temora, New South Wales.

H. A. Ward \* points out that the Willamette meteorite was discovered near the border of Clackamas County, Oregon, in the autumn of 1902. It is remarkable for its very great size, its extreme dimensions as taken by the author being as follows: length, 10 feet  $3\frac{1}{2}$  inches; breadth, 7 feet; vertical height, 4 feet; circumference of base, 25 feet  $\frac{1}{4}$  inches. It has a roughly conical form, with an oval base and dome-like summit. Its weight is estimated as being approximately  $13\frac{1}{2}$  tons. When the mass was found the cone-shaped portion was below, while the flat base was near the surface of the ground. The former, which was obviously the front side in the progress of the meteorite through the air, shows in the first place a border area quite covered with the usual pittings; also a number of round well-defined boreholes, mostly near the lower border, explained by the disappearance of cylindrical nodules of some sulphide as troilite; and, finally, a series of deep open basins and broad channels of great size, which are regarded as owing their origin to the friction of the air compressed in the rapid passage of the meteorite. The base of the mass, 10 feet by 7 feet in dimensions, is also remarkable in another way, since the once continuous surface is now largely replaced by a labyrinth of basin-like cavities, some of them very large. These are believed to have formed by the decomposition of the mass under the action of terrestrial agencies, chiefly water, as it lay for an unknown period with the side exposed. An etched surface of the iron shows the usual crystalline figures, and assigns the meteorite a place in the group of octahedral irons. The analysis shows that the mass contains 8 per cent. of nickel. The plates accompanying the paper gives striking views of the remarkable features of this extraordinary mass. The ownership is at present the subject of litigation, so that the final disposition of the specimen is yet in doubt.

The Canyon City meteorite from Trinity County, California, is described by H. A. Ward. †

L. C. Glenn ‡ gives some particulars of a new stony meteorite, weighing about 11 lbs., found in Hendersonville, North Carolina, and of a new piece of the meteoric iron from Smithville, Tennessee.

\* *Proceedings of the Rochester Academy of Science*, vol. iv. pp. 137-148.

† *American Journal of Science*, vol. xvii. pp. 383-384.

‡ *Ibid.*, pp. 215-216.

## II.—IRON ORE MINING.

**Search for Magnetic Ore Deposits.**—E. Haanel\* describes the methods used for the examination of iron ore deposits by magnetic measurements. In addition to the methods described in the papers read before the Iron and Steel Institute by B. H. Brough,† by G. Nordenström,‡ and by H. Louis,§ the author describes a new instrument, the Thomson-Thalén magnetometer, which, based upon a zero method, especially facilitates the determination of the vertical intensity over magnetic ore fields.

**Hand Drills in Iron Ore Mines.**—W. Charlton|| describes the introduction and use of ratchet and other hand machine drills, which have displaced to such a large extent the old jumper in the iron ore mines of the Cleveland district. At first they met with some opposition, as it was considered by the miners that blast holes should have the triangular form to which they had been accustomed. Illustrations are given of the following drills:—Hardy ratchet, Pendulum, Gray-Tarbit, Hall, Blackett-Hutton, Livingstone, and Hardy rotary drills. The drawback to the machine, caused by the loss of time in setting a stand, is largely overcome by using a bar driven into the face or nearest suitable point, that support being found quite sufficient.

**Rock Drills.**—The results of trials of rock drills for air consumption are given by J. B. Carper,¶ E. Goffe, and W. C. Docharty. The consumption of free air, used at 80 to 70 lbs. pressure, varied from 13 to 30 cubic feet per cubic inch drilled.

An illustrated article on electric rock drills has been published,\*\* in which a section is given of the percussive drill made by the Union Electricity Company.

The processes of drilling and blasting are described by N. W. Parlee.††

**Open-Cast Working.**—There seems to be a tendency to revert to

\* "The Location and Examination of Magnetic Ore Deposits," Ottawa, 1904.

† *Journal of the Iron and Steel Institute*, 1887, No. I. p. 289.

‡ *Ibid.*, 1898, No. II. p. 35.

§ *Ibid.*, 1899, No. I. p. 80.

|| *Transactions of the Institution of Mining Engineers*, vol. xxiv. pp. 526-537.

¶ Paper read before the Mechanical Engineers' Association of the Witwatersrand; *Mining Journal*, vol. lxxv. pp. 479, 507, 538, 574.

\*\* *Boletín Minero*, vol. vii. pp. 37-39.

†† *Journal of the Canadian Mining Institute*, vol. vi. pp. 376-389.

open-cast workings, especially in the Mesabi district, on account of improvements in handling the stripping.\*

Illustrations are given † of the Stevenson mine and of the Burt mine, both open-cast workings on the Mesabi range.

A. Macco ‡ gives some good illustrations of modern American steam shovels.

An article has been published § dealing with open-cast working. Discussing the limit of depth of open workings, the author points out that the Mekta-el-Hadid iron mines have reached a depth of 60 yards and the iron mines of Haute Marne 50 yards. At Dannemora the workings are 135 yards deep, whilst at the Popocatepetl sulphur mines the excavation is 350 yards in depth.

**Winding Plant at the Oliver Mine.**—F. Drake || gives particulars of the winding plant at the Sibley and Savoy shafts of the Oliver Mining Company at Ely, Minnesota. At the Sibley shaft 425 tons are raised in two compartments, 5 by 6 feet, from a depth of 626 feet in twenty-four hours. At the Savoy shaft 700 tons is raised from a depth of 619 feet in compartments measuring 6 feet square. The latter shaft is inclined  $1\frac{3}{8}$  inch per foot. Illustrations and dimensions are given of the cages and skips used. The shafts are 1500 feet apart and are worked from a single hoisting plant having two drums worked by a pair of Corliss engines, rated at 2000 horse-power. Each drum handles 14,000 lbs. of ore, 6000 lbs. rope, 3500 lbs. cage, and 5000 lbs. skip. The unbalanced load is 21,000 lbs. The engine works non-condensing with steam at 125 lbs. pressure. Its cylinders are 28 by 60 inches, 36 feet apart, driving direct on to a 14-inch main shaft carrying the two drums, 9 feet long and 10 feet in diameter. Steam band brakes are used. An automatic appliance cuts off steam when the cages are 360 feet below the landing, and automatically operating brakes are also provided. The head-gear is of steel framework, enclosed in a casing, and of this dimensioned illustrations are also given.

**Shaft at the Ashland Mine.**—H. F. Ellard ¶ gives a description

\* *Iron Age*, January 7, 1904, p. 108.

† *Iron Trade Review*, September 10, 1903, pp. 46-47.

‡ *Glückauf*, vol. xxxix. pp. 1125-1129.

§ *El Minero Mexicano*, vol. xliii. pp. 193-194.

|| *Engineering News*, vol. 1. pp. 449-453.

¶ Paper read before the Lake Superior Mining Institute; *Engineering News*, vol. 1. pp. 306-308; *Mines and Minerals*, vol. xxiv. pp. 128-132.

of the new No. 9 shaft at the Ashland mine. It is sunk in diorite at a distance of 155 feet from the foot-wall at an inclination of  $60^\circ$  from the horizontal. It is rectangular in section,  $12\frac{1}{2}$  by  $18\frac{1}{2}$  feet in dimensions outside the timbers, which are 14 inches square; but an extra 8 inches of rock had to be broken out as a rule each way. The shaft is divided into six compartments, one 5 by  $9\frac{3}{4}$  feet for a cage, two  $4\frac{3}{4}$  by  $5\frac{3}{4}$  for skips, one  $1\frac{3}{4}$  by  $2\frac{3}{4}$  for counter-weight, one ladder way  $2\frac{1}{2}$  by  $2\frac{3}{4}$ , and one for pipes  $2\frac{3}{4}$  by  $4\frac{1}{2}$  feet. The shaft was partly sunk and partly driven by rising from the levels in fifty weeks, 864 feet being driven upwards at the rate of 2.88 feet daily, and 1032 feet sunk at 3.44 feet daily. The skips hold 72 cubic feet. The cage has two decks, and weighs 2 tons with its wheels, safety-catches, &c. The head-gear is of steel, and contains two ore pockets with a combined capacity of 100 tons. Costs of sinking are given.

**Iron Ore Mining in Minnesota.**—In his monograph on the Vermilion iron-bearing district, J. Morgan Clements \* describes fully the methods of mining the iron ore in this region. The two systems invariably adopted are either the overhand stoping or the caving system, and these are illustrated by a number of sections and photographs. Some notes on prospecting are also given.

E. J. Carlyle † describes the Pioneer iron mine, Ely, Minnesota.

**Iron Ore Mining in New York.**—A plan of the Mineville magnetite deposits is published ‡ with some historical notes, illustrations of the workings, and a detailed account of the magnetic dressing plant. A scheme is being worked out for generating electric power from the loaded waggons on the inclines so as to return the empties. At the present power-station is a 750-kilowatt alternator, but other generators are also in use. Electrically driven winding-engines, pumps, and air compressors are at work.

**Fire-damp Explosion in an Iron Mine.**—On October 24 a serious explosion of fire-damp occurred at the Axpe-Arrazola iron ore mines in Biscay. Six persons were injured. § Gas explosions in metalliferous mines are also recorded by J. B. Jacquet || and others.

\* *Monographs of the United States Geological Survey*, vol. xlv. pp. 234-246.

† Paper read before the Canadian Mining Institute, March 1904.

‡ *Iron Age*, December 17, 1903, pp. 10-19.

§ *Revista Minera*, vol. liv. p. 567.

|| *Mining Journal*, vol. lxxv. p. 224.

**Sanitation at Iron Mines.**—Serlo \* describes the measures adopted in the iron ore mines of Lorraine to prevent the introduction of ankylostomiasis.

J. S. Mennie † describes a new changing-house at the Cliffs Shaft iron ore mine in the Marquette district.

**Handling Iron Ore.**—An illustration is given ‡ of the Greenway machine erected at the Oliver mine, Marquette, for breaking up frozen ore in the railway waggons so that it can be unloaded. It consists of an augur-like tool, carried by an overhead gantry, the tool being 9 feet long and 12 inches in diameter.

The Bousse conveyor is described and illustrated by M. Buhle.§ It consists of a number of small waggons running on rails and coupled together, this coupling being of a universal character and admitting of each waggon being separately moved, and adapting itself generally to curves in a way that is not possible in many similar systems of conveying appliances. The author considers the Bousse conveyor to possess many advantages.

H. Rupprecht|| deals with the modern types of conveying apparatus employed at mines.

Recent improvements in appliances for transport are described by E. Siermann.¶

A number of mechanical conveyors for iron ore, coal, coke, and ashes are described and compared by Frahm.\*\*

The question of the possible reduction in freight charges on minette ore and coke in Germany is discussed.††

An illustrated description has been published ‡‡ of the wire-rope ways for transporting iron ore erected at Vivero in Galicia by the Vivero Iron Ore Co. Ltd.

S. de Zomboria §§ discusses the limits for rendering the working of

\* *Glückauf*, vol. xl. pp. 34-35.

† Paper read before the Lake Superior Mining Institute; *Iron Trade Review*, August 27, 1903, p. 44; *Engineering and Mining Journal*, vol. lxxvi. pp. 395-396; *Mines and Minerals*, vol. xxiv. pp. 159-160.

‡ *Iron Trade Review*, August 27, 1903, p. 44.

§ *Stahl und Eisen*, vol. xxiii. pp. 1326-1332, with seventeen illustrations.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 7, 21-22, 31-34.

¶ *Chemische Zeitschrift*, vol. iii. pp. 301-303.

\*\* *Stahl und Eisen*, vol. xxiii. pp. 1038-1043, with seventeen illustrations.

†† *Ibid.*, pp. 1230-1237.

‡‡ *Galicia Minera*, vol. ii. No. 33.

§§ Paper read before the American Mining Congress, Deadwood; *Engineering and Mining Journal*, vol. lxxvi. p. 513.

wire-ropeways automatic. It is considered that the system in which the buckets are permanently fixed to the rope and used with automatic loading and unloading appliances, is the most promising.

Some correspondence from A. Painter and R. D. Seymour on wire-ropeways in America has also been published.\*

Illustrations are given † of the ore docks at Duluth.

An illustration is published ‡ of a turret-deck steamer that is to carry a load of about 10,000 tons of iron ore. She is 440 feet long, 62 feet beam, and 29 feet in depth, and is provided with engines of 2400 horse-power, which when the vessel is fully laden will give her an estimated speed of ten knots. She has been built for a German firm, and is intended for the conveyance of Grängesberg ore from Sweden to Rotterdam.

### III.—MECHANICAL PREPARATION.

**Improvements in Ore Dressing.**—The present methods of the mechanical preparation of ores are discussed by H. Lenicque.§ The author describes his improved oscillating trommel, in which the difficulties hitherto experienced with this type of apparatus appear to have been fully overcome. The improvement consists in the method of applying the force which is necessary to maintain an oscillating movement of the trommel in such a manner as to avoid all shocks. Further chapters are devoted to the process of the wet concentration of ore, to the Lenicque revolving-table, and to the electro-magnetic separation of ore.

**The Concentration of Iron Ores in Sweden.**—According to W. Petersson|| the concentration of Swedish ores is effected either by the magnetic or by the wet method. The author describes the several apparatus employed for the magnetic process, including the Monarch, the Gröndal, the Heberle, the Fröding, the Eriksson, and the Foragren separators. The installations at different localities are also briefly described. He then deals with those installations where the wet method of concentration is carried out, as at Långban, Risberg,

\* *Engineering and Mining Journal*, vol. lxxvi. pp. 398, 514, 705.

† *Ibid.*, pp. 394–395.

‡ *Stahl und Eisen*, vol. xxiv. pp. 164–165, with one illustration.

§ *Bulletin de la Société de l'Industrie Minérale*, vol. ii. (series 4), pp. 919–948.

|| *Jernkontorets Annaler*, vol. lviii. pp. 251–362.

Kantorp, and other places. Some experiments are also reported on the concentration of ores of non-uniform character.

It was formerly customary in Sweden to wash the small iron ore by hand, but in 1883 mechanical means were adopted at the Långban mine, and in 1885 magnetic methods were adopted for the separation of magnetite from the waste heaps on the Slotterberg mine. The number of these magnetic separation plants gradually increased after 1892, and they have all given excellent results. Amongst these attention may be especially directed to the plants at the Skött mine, at the Dalkarlsberg near Vigelsbö, Bjornberg, and above all others to the magnificent plant at Grängesberg. Either the magnetic or the wet methods, or a combination of the two, is now customary, and these are passed in review and their gradual development drawn attention to.\*

The first magnetic separation of iron ores in Sweden appears to have taken place about 1884, but magnetic enrichment was not introduced until 1894, when a Monarch separator was put into operation at Stockholm. In 1897 another separator, designed by G. Gröndal, was put into successful use at Pitkäranta, Finland, and about the same date another such separator was designed by Heberle. In 1900 a second form of separator was devised by Gröndal and placed on the market, and in 1901 other magnetic separators were constructed by Fröding and by Eriksson. In 1902 came Forsgren's separator, and in 1903 a third design by Gröndal. Thus within nine years of the first introduction into Sweden of the Monarch separator, no less than seven other such separators of Swedish design have come into operation. At the Swedish iron ore mines in 1902 there were 11 ore-washing plants and 17 magnetic separation plants, which together yielded 188,578 tons of treated ore.

In addition to these Swedish separators a number of others were also designed elsewhere. These included separators for the treatment of but feebly magnetic minerals. Towards the close of 1700 it was shown that not only were magnetite and magnetic pyrites attracted by the magnet, but that all ferruginous minerals were also attracted to a greater or a lesser degree. No practical use was made of this knowledge, however, until 1896, when the Wetherill separator was introduced, though the principle on which Wetherill depended had been utilised in the separators designed by Maxim in 1886 and by Aylesworth and Payne in 1897, but Wetherill was the first to deal

\* *Oestereichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 165-168, 179-181.



practically and successfully with the enrichment of feebly magnetic ores by magnetic means. Various forms of separator are described in some detail, including another not referred to above—the Mecher-nich type for feebly magnetic substances.

Some details relating to the separation of iron ore and apatite are extracted\* from an article by L. de Launay on the iron ores of Scandinavia.† The original attempts that were made to separate the apatite from the Gellivare ore were failures, and in 1897 a process was introduced for its separation from the worthless phosphoric ores by mechanical means. This consists in grinding the ore very fine, separating the magnetite magnetically, and jigging out the red iron ore. The residue, consisting of apatite with some felspar, mica, and quartz, is converted into tetraphosphates of sodium and lime.

At Grängesberg an entirely different method is adopted, the magnetite being simply separated magnetically. The fine magnetite being difficult to dispose of in this form, it is converted into briquettes. In 1899 the Luleå plant treated 300 tons per day, employing 50 workpeople in two shifts, and requiring 750 horse-power. It yielded some 65,000 tons of pure magnetite, a little red iron ore, 15,000 to 20,000 tons of impure magnetite, with 0·6 per cent. phosphoric anhydride and 8000 to 10,000 tons of tetraphosphate, with 21·5 per cent. of soluble phosphoric acid.

**Magnetic Separators.**—Magnetic concentration is dealt with by R. H. Richards,‡ who gives a very full bibliography of the subject.

L. Fabre§ describes the recent progress in the magnetic concentration of ores.

Hecker|| describes the two new magnetic ore separators in use in Sweden, one invented by E. Forsgren and the other by Eriksson.

In the Forsgren magnetic separator as used at Falun, Sweden, a wheel placed horizontally rotates between a pair of fixed magnetic poles of opposite polarity.¶ This wheel consists of a number of wedge-shaped pieces of iron—"secondary poles"—well isolated from each other. They are grouped in two concentric rings, the points being directed towards one another at a distance of some 1·97

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 125-126.

† *Annales des Mines*, vol. iv. pp. 49-106, 109-211.

‡ "Ore Dressing," New York, 1903.

§ *La Revue de Chimie Industrielle*, vol. xv. No. 170.

|| *Glückauf*, vol. xi. pp. 77-81.

¶ *Blad för Bergshandlingens Vänner inom Orebrölän*, vol. xi. Part II. 1903.

inch to 2.86 inches, according to the quantity of ore-bearing material to be treated, its size, and its degree of magnetic intensity. Between these rings the material is brought into the magnetic field, the ore being held between the poles and the dead material falling through the apparatus. As the distance from the poles increases, so the least magnetic portions begin to fall away, with the result that a constant succession of falling particles of increasing iron contents results, the residual magnetism of the iron itself being finally eliminated by making it pass between the poles of a permanent magnet, at which point all the material still adhering falls off.

The apparatus is extremely simple and exceptionally resistant to wear, and but little power is necessary at first for magnetisation, as the ore material has to pass immediately in front of the poles. Its greatest advantage, as compared with other similar apparatus, consists in its being able to separate unclassified material from the size of slimes up to pieces of about 1.2 inch. It is just with material of this latter size that it ceases to be a payable matter to separate any further by hand, and the result has been that most material of this size at Swedish mines has up to now been thrown on the dumps. It is found that the Wenström separator is not so good for materials such as that mentioned above as for larger sizes, and the Gröndals and Frödings separators will not deal with it at all, unless it has all been first reduced to a fine state of division. With the Forsgren apparatus, however, this preliminary grinding is no longer necessary. This may lead at times to a considerable saving from the financial point of view. One Forsgren machine of large size will treat from 8 to 10 tons of material per hour. This is much cheaper, of course, than would be the use of several similar machines of smaller size. Test results are given.

L. Fabre \* gives an account of the recent progress in the magnetic separation of ores. He gives several illustrations of the new type of Wetherill machine. The most recent type of Wetherill magnetic concentrator is also described and illustrated by H. Ostwald.†

W. Wells ‡ discusses the magnetic concentration of iron ore, and describes the experiments made with the iron ores from Ontario.

In another paper the progress in the magnetic concentration of iron ore is further described by J. W. Wells.§

\* *Rassegna Mineraria*, vol. xix. pp. 225-229.

† *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 106-108.

‡ *Report of the Bureau of Mines of Ontario*, vol. xii.

§ *Journal of the Canadian Mining Institute*, vol. vi. pp. 6-20, with twenty plates.

F. T. Snyder \* deals with magnetic separation, reviewing the history of the process, and showing that important progress has been recently made. In the discussion which followed it appeared that the author is the inventor of a magnetic concentrator of a new type, with which very successful work has been done.

An elevation of the plant, diagrams of the working, and diagrammatic section of the Ball magnetic concentrator has been published † to show the plant at the Hibernia mine, New Jersey. The run of the mine is passed through a 16 by 24 inch Buchanan crusher running at 225 revolutions, and passes to a 2·5-inch screen. Coarse material passes through corrugated 36 by 18 inch Buchanan rolls running at 126 revolutions, and returns to the screen. The 2·5-inch stuff is treated in a Ball magnetic separator, which makes two products. The tailings go to a second separator, running more slowly and worked at a higher potential. Lean ore from the machine is further crushed in Buchanan rolls running at 125 revolutions, and is treated in a third separator, which gives fine ore. The tailings from both the second and third separators are treated in sizing screens, and is sold as rock. The mill treats 800 tons per double shift. Average analyses show 47·6 per cent. of iron in the crude ore, 58·2 in the coarse concentrates, 54·61 in the fine concentrates, and 23·55 in the tailings; but the latter includes felspar carrying 7 to 8 per cent. of iron.

Illustrated details are published ‡ of the magnetic concentration plant at the Mineville magnetite mines, Port Henry, New York. The old bed ores contain 60 per cent. of iron and 1·35 to 2·25 of phosphorus in the form of apatite. The ore is sometimes cobbled by hand, and the second grade ore or the run of the mine, if all is treated, is taken to a crushing plant comprising a 30 by 18 inch and a 36 by 6 inch Blake crusher and 36 by 14 inch rolls. All material is broken to pass a 6-mesh screen and passed through a vertical dryer. Then it is made into four sizes of 30, 16, 10, and 6 mesh, and treated in four Wetherill separators, and two Ball and Norton separators and Rowand machines. Tailings are treated in a Wenström separator. The plant will treat 800 tons daily, giving 680 tons of concentrated ore and 60 tons each of first and second grade apatite. Sections of the magnetic separators are given.

In correcting some historical notes given in the above account,

\* Paper read before the Canadian Mining Institute, March 1904.

† *Iron Age*, October 22, 1903, pp. 16-17.

‡ *Ibid.*, December 17, 1903, pp. 10-19.

J. N. Judson \* quotes from some publications of 1830 and 1832, showing that magnetic separators were then treating iron ore at the Franconia Iron Works in New England, with the result of an economy in fuel for smelting. Reference is also made to Browning's patents, obtained in the United States in 1810 and 1814.

#### IV.—METALLURGICAL PREPARATION.

**Calcining Iron Ore.**—John Cadman,† who has previously described‡ the method of calcining the blackband ores of North Staffordshire, now adds a description of the method employed with clayband ironstone in the same district. As this material does not contain sufficient carbonaceous material, 3 to 4 per cent. of fuel has to be added, and the rucks are made 8 feet instead of about 6½ feet. The burnt stuff is not graded. Loss in weight during the burning amounts to 18 or 20 per cent.

**Briquetting Ore.**—R. Schorr§ briefly reviews the manufacture of briquettes from ore, flue dust, and similar material, and states that the cost of repairs is but small. In America there are two types of machinery at work, one using the ore mixed with milk of lime and the other treating dry material. Hand-made bricks will be found economical when labour is cheap.

F. G. Stridsberg|| describes Gröndal's method of briquetting iron ores.

\* *Iron Age*, February 11, 1904, pp. 39-40.

† *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 116-119.

‡ *Journal of the Iron and Steel Institute*, 1902, No. 1. p. 434.

§ *Transactions of the American Institute of Mining Engineers*, February 1904.

|| *Affärsvärlden*, vol. iv. p. 533.

## REFRACTORY MATERIALS.

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**Fireclay.**—The fireclay found by P. N. Bose \* near Jowai, in Assam, yielded excellent fire-bricks. Its occurrence in the vicinity of good coal makes it available for brick manufacture.

Ludwig † discusses the relations that exist between the chemical compositions of clay and their relative fusibility. To ascertain this it is in the first place necessary to find out how the various foreign admixtures affect the main clay mass, and what chemical changes take place when the clay is fused. It is noticed in the case of every solution that there is a lowering of the melting-point. Silicate mixtures when fused must be looked upon as mutual solutions of various silicates and oxides in one another. The lowest melting-points must therefore be possessed by those mixtures whose composition differs to a maximum extent from that of a definite silicate. The Seger cones are examples of this. Similarly the melting-point of the silicate  $\text{CaO}, \text{SiO}_2$  is not increased by the addition of a moderate quantity of quartz, but lowered. When a fireclay is heated above the melting-point of its most fusible constituent solution, a small quantity of this solution is first formed, low in alumina; as the temperature rises it takes up further quantities of silica and smaller quantities of alumina, and so on, until the clay fuses, the quantity of the solution having become much greater than that of the residual undissolved material. The same law holds good as applies to all dilute solutions; that an equal number of molecules of different substances dissolved in an equal quantity of the fused material lower the melting-point by the same amount, entirely independent of the varying chemical nature of these admixtures, and it is quite immaterial whether they are bases or acids. It is therefore impossible to judge of the character of a clay by adding together the quantities of the impurities it contains. It must be considered molecularly. For instance, the final analysis of a Grünstädt kaolin shows  $\text{Al}_2\text{O}_3 + 2.125 \text{ SiO}_2 + 0.0755 \text{ RO}$ .

\* *General Report of the Geological Survey of India*, 1903, p. 10.

† *Stahl und Eisen*, vol. xxiv. pp. 367-368.

Here all that can be shown by the analysis of a clay is expressed by two numbers. The author has analysed eighty-five clays in this way, and compared their theoretical melting points with the actual ones as determined by the Seger cone. In the majority of cases there was a close agreement between the two. Exceptions were most marked in the case of those clays that were very impure; but even then they always lie in the same direction, as it was found that the actual melting-point was never below what had been calculated for the clay theoretically. One of the causes of variation lay in the iron contents of some clays, and was due to ferric oxide splitting up into the ferrous form when the clay was melted down, one molecule then becoming two. The time to complete this change was found to be greater than necessary to fuse down the clay in a Deville furnace. The result was that the melting-point consequently appeared to be too high. The chief cause of the variations noted is that the clays are not homogeneous mixture. Analysis is consequently of evident value in adjudging the character of a fireclay; but the value of a fire-brick depends on other points as well as its chemical composition. If a firebrick is to come in contact with molten clay it would be better to have a more impure brick if dense, than a purer but porous brick, as the latter would absorb too much of the molten slag and so tend to fuse down more readily than would the other and denser brick.

**Firebricks.**—H. Ries\* gives some notes on the firebrick industry in New Jersey. The bricks are made from clay dug round Woodbridge and elsewhere in Middlesex county, mixed with ground firebrick, siliceous clay, and gravelly felspar occasionally. The refractoriness of the clays vary from Seger cone 33 to 35 for one quality and from 27 to 30 for the other, while the bricks vary between cones 27 and 33. They are made by hand or soft mud machines, and occasionally by the stiff mud process. The usual temperature of burning varies between cones 10 and 12. A number of analyses of clay and bricks are given. Few contain less than 70 per cent. of silica, and titanium oxide is generally present, in one case to the extent of 2.65 per cent.

**The Schröder Kiln.**—A. Pohl† describes the Schröder kiln for fire-resisting materials. It is of the chamber type, and is stated to

\* *Transactions of the American Institute of Mining Engineers*, October 1903.

† *Stahl und Eisen*, vol. xxiv. p. 367.

consume only 5 to 7 per cent. of fuel. The author has experimented with such a kiln with 15 chambers, steam being passed in through the fire-bars. These were rapidly destroyed when steam was used. The kiln generally did not work at all well until considerably modified. Other types of kiln are also mentioned.

**Graphite.**—The occurrence of graphite at Schweine in Moravia is described by F. Kretschmer.\* Details are given of the methods of mining and dressing employed.

**Bauxite.**—The existence of bauxite in the Liassic strata to the east of Gijon, Spain, is reported.† Analyses yielded the following results:—

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO.	CuO.	H <sub>2</sub> O.
10·87	51·64	0·16	0·63	36·60
16·80	44·50	0·60	0·83	35·95

This is the first time that bauxite has been found in Spain. The composition of the mineral is, however, not such as to render it of commercial value.

At a meeting of the German Geological Society, E. Kaiser‡ described the occurrence of bauxite in Germany.

**Magnesite.**—In a course of Cantor lectures on the mining of non-metallic minerals, Bennett H. Brough§ dealt incidentally with refractory materials. For lining steel furnaces dolomite has to be dead-roasted until all the carbonic acid and water are removed. For this purpose magnesite, native magnesium carbonate, is frequently used, and would be exclusively used if the supply were not limited and the price correspondingly high. It occurs in thick beds in Styria, in Eubœa, in Hungary, at Frankenstein in Silesia, at Krubschitz in Moravia, at Snarum in Norway, and in California and Texas. The purest variety occurs in the Salem district in Southern India. According to unpublished information furnished by H. G. Turner, the deposits are situated two miles from Salem, 200 miles from the port of Madras, and an equal distance from the port of Beypore on the west coast. The depth of the deposit is unknown. The mineral contains 47·35 per cent. of magnesia, 51·44 per cent. of carbonic acid, 0·30 per cent.

\* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. lii. pp. 353-373.

† *Mining Journal*, vol. lxxv. p. 118.

‡ *Glückauf*, vol. xl. p. 347.

§ *Journal of the Society of Arts*, vol. lii. pp. 156-157.

of ferric oxide and alumina, and 0.27 per cent. of moisture, 0.22 per cent. of insoluble siliceous matter, and no lime. Its specific gravity is 3.056. It is quarried and ground in mills of primitive construction. In the preparation of the magnesite for the manufacture of fire-bricks, and for linings and hearths for steel furnaces, excellent results have been obtained. Magnesite bricks now on the market are deficient in refractory qualities because the minerals of which they are made contain too great a proportion of other ingredients. Thus the Hungarian magnesite contains 3.2 per cent. of ferrous oxide, and the Grecian magnesite contains 4.02 per cent. of carbonate of lime. Nor are these magnesites properly dead-burnt or shrunk before being made into bricks, so that these bricks contract and lose shape when subjected to great heat, as in metallurgical processes, where bricks of stable quality are indispensable to prevent constant renewals and repairs. In order to produce a good magnesite brick, that is, a brick consisting essentially of pure magnesium oxide, it is necessary not only to dead-burn the crude material, but to subject it to such an intense heat as to cause it to crystallise. Mere calcining in a cupola, or even in a Siemens furnace, cannot effect this physical change in the condition of the substance. The only heat which can do this is that of the electric furnace, and Indian magnesite is pure enough to undergo the ordeal. Recent experiments made on a considerable scale show that under the intense heat of this furnace, the Indian mineral crystallises into a hard dense mass, yielding a product of the greatest refractory quality, which is not only adapted to the manufacture of bricks, but, when powdered and mixed with some adhesive material, it affords a paste and a mortar sufficient to protect the brick walls of furnaces from attack. For instance, it has been found that when the fire-bricks, lining a melting pot in a calcium-carbide furnace, were fixed with mortar and covered with a wash of this crystallised and ground magnesia they lasted for 200 hours without repair, whereas the unprotected bricks required repair after a five hours' heat. This crystallised mass itself, without further preparation than being crushed to suitable dimensions, will, it is thought, prove of special value as a refractory material in metallurgical practice. An important point in connection with its use as linings for electric furnaces is that magnesite, unlike lime, does not form a carbide with carbon.

The deposits of magnesite in the Island of Eubœa are among the largest and richest known. Quarries are worked by the Anglo-Greek Magnesite Company, Ltd., the output in 1901 being 13,000 tons of



raw and 2100 tons of calcined magnesite. The company has ten kilns in operation, and can turn out about 70 tons of calcined magnesite a day. At the Greek magnesite mines until recently, roughly built kilns fired by wood were employed for calcining the ore, which required a large quantity of fuel. In recent years, however, modern shaft calciners have been built, and a solid lignite coal is used.

# FUEL.

## CONTENTS.

	PAGE		PAGE
I. Calorific Value . . . . .	501	VI. Natural Gas . . . . .	533
II. Coal . . . . .	504	VII. Artificial Gas . . . . .	534
III. Charcoal . . . . .	515	VIII. Coal Mining . . . . .	538
IV. Coke . . . . .	516	IX. Coal Washing and Screening	557
V. Liquid Fuel . . . . .	524		

### I.—CALORIFIC VALUE.

**Calorimetry.**—J. S. S. Brame\* and W. A. Cowan have made a comparison of various types of calorimeters, including those of Thompson, Fischer, and Mahler. The calorimetric bomb of the latter is considered to give the best results.

For determining the value of fuel by Parr's method, M. Kohl † has designed a calorimeter which is based on the principle of securing the complete combustion of the fuel to be tested without means for the admission or escape of gas, so as to permit of sealing up the apparatus entirely. Salts, rich in oxygen, are introduced along with the powdered fuel in the bomb, and are decomposed at the moment of ignition but combine again with the gaseous products, thus preventing an excess of pressure.

**Calorific Value of Coal.**—C. von John ‡ discusses the calculation of the elementary analysis of coal with reference to the proportion of sulphur, and the influence of the various methods of calculation on the amount of oxygen and on the heat units calculated.

\* *Journal of the Society of Chemical Industry*, vol. xxii. pp. 1230-1233.

† *Mittheilungen aus der Praxis des Dampfkessel-Betriebes*, 1903, pp. 973-974.

‡ *Verhandlungen der k.k. geologischen Reichsanstalt*, 1904, pp. 104-111.

A report has been published\* of the experiments made by the Boiler Inspection Society of Dortmund on the heating power of coal.

The Society of Proprietors of Boilers in Alsace in 1902 carried out 204 determinations of the calorific value of fuels from German, French, and Belgian sources, and these are now arranged in tabular form for comparison.†

Oellerich ‡ calculates the calorific value of brown-coal briquettes in raising steam. The results of tests with this class of fuel are given.

Myles Brown § urges the importance of regular tests of coal for the calorific value.

J. B. C. Kershaw, || in dealing with fuel economy from the chemical point of view, gives a large number of laboratory tests, and shows the relation of price and calorific value. The approximate rather than the elementary analysis of fuels is to be preferred.

**Pyrometry.**—J. A. Harker ¶ gives an account of a comparison of platinum thermometers and thermo-junctions with the gas thermometer at the National Physical Laboratory. The results of Callendar and Griffiths are confirmed, and show that Callendar's parabolic formula may be used over a wide range.

H. L. Callendar \*\* has dealt with electric methods of measuring temperatures by platinum resistances and by thermo-junctions. The increase of platinum resistance follows a parabolic curve, but the curves for other metals are of varied forms. These curves and also curves for thermo-junctions are given. Various constructions of these pyrometers and of the recording instruments are considered and also their applications.

The Siemens pyrometer and appurtenances used with it are illustrated and described. ††

H. Rabe ‡‡ discusses the modern methods for the determination of high temperatures. It is remarkable how little suited for use in

\* *Glückauf*, vol. xxxix. pp. 1177-1179.

† *Mittheilungen aus der Praxis des Dampfkessel-Betriebes*, 1903, pp. 728-729.

‡ *Ibid.*, pp. 666-668.

§ *Engineering and Mining Journal*, vol. lxxvi. pp. 965-966.

|| Paper read before the Liverpool Engineering Society; *Engineer*, vol. xcvii. pp. 171-172.

¶ *Proceedings of the Royal Society*, vol. lxxiii. pp. 217-219.

\*\* Lecture at the Royal Institution, March 1904; *Engineering*, vol. lxxvii. pp. 336, 370, 402.

†† *Iron and Coal Trades Review*, vol. lxxviii. pp. 41, 42.

‡‡ *Chemiker Zeitung*, vol. xxviii. pp. 39-40.

practical work many theoretically excellent instruments are. They are usually not only extremely fragile and inaccurate in their readings except with the use of corrections, but the manufacturers supply so little information as to their manipulation, that the person who has to use them in practice has first to learn by experience how to use them for the determination of high temperatures. Glass thermometers can be used up to a temperature of about  $550^{\circ}$  C. This is a fact well enough known; but what is not so well known is that they alter very greatly in their readings in the course of time if constantly used. For a good glass thermometer it is necessary that a suitable heat-resisting glass should be used, and one, too, that has been long enough exposed to a high temperature, *i.e.* artificially aged. The gases that are to be used in these thermometers, nitrogen and carbon dioxide, together with the mercury and the inner portions of the glass, are often not absolutely pure, and this leads to errors. The metallic casing of this form of thermometer should be strong enough to permit of its being moved about either when hot or when cold. There should be no orifice in this casing in the neighbourhood of the mercury bulb, as dust settles in it and renders the readings more difficult. The scale, divisions, and numbers should be such as to enable the reading to be performed with ease. The author prefers for practical use the glass thermometer as arranged by G. A. Schultze of Berlin.

With regard to electrical pyrometers, the form devised by Keiser and Schmidt of Berlin has been found by the author to give excellent practical results, especially since it has been found possible to replace the costly platinum or platinum-rhodium of the Le Chatelier pyrometer by iron in the determination of relatively low temperatures. Instead of iron an alloy termed constantane is also used for this purpose. Still the galvanometers used in the readings are for many technical purposes not sufficiently accurate, as they give results which vary by as much as  $50^{\circ}$  C. from the true temperature. This is partly due to too great an internal resistance on the part of the pyrometer, and on the other hand to too small an internal resistance on that of the galvanometer. The author has drawn the attention of Keiser and Schmidt to this fault, and galvanometers are now constructed which are accurate to 1 degree. The wires used in pyrometers of these types are apt to be spoilt either by oxidation or from mechanical causes, and it is shown how this may be partly avoided. The author enumerates the various advantages and disadvantages of electrical

pyrometers and glass thermometers for low temperature determinations.

The association of German works making fire-resisting products has pointed out that pyrometers marked off in degrees C. are not accurate at high temperatures. Pyrometers even of the same make, and compared under similar conditions, will show temperatures which vary greatly even among themselves, and far more when compared with the results afforded by pyrometers of other makes. They are therefore not reliable as a means of determining really high temperatures. For this reason the association suggests that the well-known Seger cones should be generally accepted as a continuation for high temperatures of the centigrade scale. An accurate determination is, for instance, possible if the temperature is stated to be that shown by the Seger cone No. 35, whereas the statement 1800° C. might be quite illusory.\*

In the Morse pyrometer, of which illustrations are given,† the temperature is determined by comparing the colour of the heated body with that of the incandescent electric lamp, to which the current is supplied through a graduated set of resistances so as to vary its luminosity.

H. Wanner's ‡ pyrometer also compares the light emitted from the body under observation with that from an incandescent electric lamp, a Nicol prism being used to bring the two lights to the same intensity, and the angle through which it is turned affording a measure of the temperature.

## II.—COAL.

**The Composition of Coal.**—In reference to a long series of articles, containing collected analyses of British coals and cokes, and recently reprinted in collected form, C. A. Seyler§ offers some observations on the variable manner in which assays are sometimes presented, and then discusses the data in the light of the classification he proposed || some years ago, and considers that it is upheld.

E. Donath¶ and F. Bräunlich show that brown coal and coal are

\* *Stahl und Eisen*, vol. xxiv. p. 366.

† *Iron Age*, October 22, 1903, pp. 1-2; *Iron and Coal Trades Review*, vol. lxxviii. p. 312; *Journal of the Franklin Institute*, vol. clvii. pp. 33-39.

‡ *Engineering and Mining Journal*, vol. lxxvi. p. 971.

§ *Colliery Guardian*, vol. lxxxvi. p. 1041.

|| *Journal of the Iron and Steel Institute*, 1900, No. II. p. 429.

¶ *Chemiker Zeitung*, vol. xxviii. pp. 180-182.

chemically quite distinct. The chemical composition of the material from which brown coal was formed was different to that from which coal was formed. Geological observations show that geological age, time, and pressure do not determine the nature of coal. Thus brown coal has been found of Devonian age in Russia, and true coal in Central Russia has been found with the characteristics of brown coal.

**The Origin of Coal.**—A paper by C. Grand' Eury on the formation of coal, read before the Paris Academy of Sciences, has been published.\*

**Coal in England.**—J. B. Simpson † discusses the probability of finding workable seams of coal in the carboniferous limestone or Ber-nician formation, beneath the regular coal measures of Northumberland and Durham. An account is appended of the recent deep boring made in Chopwell woods below the Brockwell seam. Five seams, but only a few inches in thickness altogether, were found.

R. Etheridge ‡ gives the result of an examination of the rocks brought to the surface at the Dover sinking.

**Coal in Austria.**—A concise description of the Austrian coal deposits has been published.§

H. Höfer || describes the occurrence of brown coal at Hart, near Gloggnitz, in Lower Austria.

An article has been published ¶ on the brown coal deposit at Steinkirchen, near Budweis. The bed is 2 to 8 yards in thickness, and has been opened up by a shaft 40 yards deep. The brown coal contains 32·20 per cent. of moisture and 13·40 per cent. of ash. It is estimated that there are 900,000 tons of workable fuel.

An article has been published \*\* on the Permian bituminous shales of north-eastern Bohemia.

**Coal in Belgium.**—Tabular statements have appeared †† showing the different kinds of coal that are found in Belgium, the uses to

\* *Echo des Mines*, vol. xxxi. pp. 457-459.

† *Transactions of the Institution of Mining Engineers*, vol. xxiv. pp. 549-571.

‡ *Colliery Guardian*, vol. lxxxvi. pp. 1145-1146.

§ *Ibid.*, vol. lxxxvii. p. 617.

|| *Geologisches Centralblatt*, vol. iv. p. 624.

¶ *Montan Zeitung*, vol. xi. pp. 97-98.

\*\* *Ibid.*, pp. 186-187.

†† *Moniteur des Intérêts Matériels*, vol. liii. pp. 3397, 3449, 3529, 3606, 3640, 3795, and 3879.

which they are put, where found, and remarks as to the extent to which the deposits have been worked out. From these it appears that the various varieties of non-caking coals are found all over Belgium and in very considerable quantity. They are chiefly used for household purposes. Bituminous coals are next dealt with. Those yielding from 15 to 17 per cent. of volatile products, and used for furnace purposes, are still found in quantity in the central coal-field and especially in Le Borinage, but they are beginning to become scarce in the districts of Liège and Charleroi. The coals used for coke production, yielding from 17 to 24 per cent. of volatile products, have been worked out in the Charleroi basin, greatly reduced in quantity in that of Liège, but exist in adequate quantity in the central basin, and are relatively abundant in Le Borinage. The coals yielding 24 to 32 per cent. of volatile products, and used for producer purposes, have been worked out in the Liège and Charleroi districts. In the central basin they still exist in small quantities, and in larger quantities in Le Borinage. The coals that are used in the manufacture of illuminating gas, and yield from 32 to 45 per cent. of volatile products, have been exhausted in the districts of Liège and Charleroi and in the central basin. They are still found in small quantities in Le Borinage.

In a coal from Charleroi, containing 15·07 per cent. of volatile matter, 7·29 per cent. of ash, and 76·64 per cent. of fixed carbon, J. Smeysters \* has found 2·38 per cent. of copper in the ash.

P. Fourmarier and A. Renier † have completed a study of the stratigraphy and palæontology of the coal measures of the north of Belgium.

The coalfield of the north of Belgium is described by X. Stainier.‡

**Coal in France.**—Breton§ discusses the possible prolongation of the Saarbrücken coalfield into France.

B. Schulz-Briesen|| observes that the continuation of the Saarbrücken coalfields towards the west and south-west into German Lorraine has been proved in recent years. In this connection the author quotes at length from recent papers on the subject by Weiss¶ and by Villain. The former recapitulates known facts, and the latter

\* *Annales des Mines de Belgique*, vol. ix. p. 126.

† *Ibid.*, vol. viii. pp. 1183-1907.

‡ *Ibid.*, vol. ix. pp. 411-450.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1904, pp. 5-18, with four plates.

|| *Stahl und Eisen*, vol. xxiv. pp. 318-319.

¶ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1903, pp. 170-191.

attempts to follow from geological considerations the extension of the Saarbrücken coal seams under the thick covering beds into the district of the Meurthe near Nancy and Pont-à-Mousson. The author does not consider that the coal deposits of France will ever suffice to render that country independent of other fuel supplies.

Coignard\* gives the following analyses of (1) lignite from the Pin, Gard, (2) lignite from the Liquisses near Nant, Aveyron, and (3) anthracite from Olympie, Gard:—

	1.	2.	3.
Moisture . . . . .	21·80	4·80	1·10
Volatile matter . . . . .	34·50	38·70	5·40
Ash . . . . .	15·60	9·80	12·40
Fixed carbon . . . . .	28·10	44·65	81·10
Sulphur . . . . .	...	2·05	...

Sainte-Claire-Deville† has published a note on some intercalations of shales and fossiliferous limestones occurring in the coal region of Escarpelle.

**Coal in Germany.**—W. Dill‡ describes the dislocations of strata observed in the two shafts of the Hansa colliery at Dortmund.

B. Schulz-Briesen§ records the observations made in exploring for coal on the left bank of the Rhine.

Some observations on irregularities in the seams in the Saar coal-fields are published by E. Kohler.||

L. von Ammon¶ has prepared for the Geological Survey of Bavaria a description of the coal measures of the Bavarian Palatinate.

F. Tornau\*\* describes the Flözberg at Zabrze in Upper Silesia, and gives an account of the stratigraphy of the Upper Silesian coalfield.

The Silesian coalfield is described by Gaebler.††

\* *Annales des Mines*, vol. iv. p. 541.

† *Bulletin de la Société de l'Industrie Minérale*, vol. ii. pp. 1113-1123

‡ *Glückauf*, vol. xxxix. pp. 1257-1262.

§ *Ibid.*, vol. xl. pp. 361-370.

|| *Geognostische Jahreshefte*, vol. xvi. pp. 63-68.

¶ Munich, 1903, 106 pages, with 24 illustrations.

\*\* *Jahrbuch der kgl. Preuss. Geol. Landesanstalt*, vol. xxiii. pp. 368-524, with two illustrations and four plates.

†† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. li. pp. 497-519.



R. Michael \* gives a detailed description of the various maps of the Upper Silesian coalfield that have been published.

B. Treptow † gives some notes on the Zwickau coalfield.

F. Heinicke ‡ describes the Miocene brown-coal deposit between Merka and Brehmen in the Saxon Oberlausitz.

F. Heinicke § also describes the deposit of Miocene brown coal at Guhra, Puschwitz, and Wetro in the Saxon Oberlausitz.

**Coal in Hungary.**—A. von Kaleczinsky || has published a description, covering 324 pages, of the occurrence of coal in Hungary, with special reference to the chemical composition of the coals and their practical importance. The coal deposits belong to various geological horizons, though they are mostly of relatively late origin. True coal is only found in workable seams in the Krasso-Szörényer county. The seams met with in the Dyas are not yet mined, but those in the Lias, in the southern section of the country, have been developed on a considerable scale at Fünfkirchen, Doman-Resicza, Auina, Drenkova, and elsewhere. The production of coal in Hungary doubled during the period 1875–99, and that of brown coal increased to more than five times the quantity mined in 1875.

The deposits of coal and brown coal in Hungary are described by A. Grittner. ¶

The geology of the Zsil valley is described by F. Nopcsa. \*\*

B. Krizko †† describes the mines of the Urikany-Zsil Valley Coal-mining Company, giving a large folding map of the district and numerous illustrations.

F. zur Mühlen ‡‡ describes the occurrence of coal in Nagy-Barod in Hungary. The coal is of good quality; it yields an analysis of 66·22 per cent. of carbon, and 3·30 per cent. of ash.

**Coal in Italy.**—T. Taramelli §§ supports the theory that the lignites

\* *Zeitschrift für praktische Geologie*, vol. xii. pp. 11–20.

† *Journal für Gasbeleuchtung*, vol. xlvi. p. 1053.

‡ *Braunkohle*, vol. ii. pp. 481–488, 497–499.

§ *Ibid.*, pp. 609–612, 637–642.

|| Budapest, 1903. Summary in *Zeitschrift für praktische Geologie*, vol. xii. pp. 97–103.

¶ *Organ des "Verein der Bohrtechniker,"* vol. xxi. No. 24.

\*\* *Bányászati és Kohászati Lapok*, vol. xxxvi. pp. 750–752.

†† *Ibid.*, vol. xxxvii. p. 83.

‡‡ *Montan Zeitung*, vol. xi. pp. 2–3.

§§ *Giorn. di geol. pratica*, vol. i. pp. 141–144; *Geologisches Centralblatt*, vol. iv. p. 709.

of the Vicentin were formed from vegetable matter transported by water in the lakes of the Eocene period. He does not regard these lignites, except that of Mount Pulli, as being of industrial value.

A rich bed of lignite has been discovered in Abruzzo.\* Subsidences caused by heavy floods in the basin of Concerviano, near the river Salto, led to the discovery of the mineral, which in many places is in beds of over 6 yards. It is of good quality, and experiments in a local foundry have produced excellent results.

N. Pellati † describes the anthracite deposits of the western Italian Alps.

**Coal in Russia.**—A. Petroff ‡ gives the results of analyses of coal from Lunjewsk on the western slopes of the Ural. The coal is a gas coal rich in ash and sulphur.

Some details of the coal resources of Siberia have been published.§ The opening up of the deposits of the southern Ussouri region is progressing and coal is being worked 12 miles from Vladivostok.

E. N. Fell || deals with mining in the Kirghiz Steppes in the southwestern part of Siberia. That part of the country seen by the author consisted of sedimentary rocks with igneous intrusions. The sedimentary rocks are chiefly sandstones and conglomerates, which have been referred to the Devonian period, and limestones of the Carboniferous period. The sandstones and conglomerates pass quickly from one to the other. Coal is found plentifully distributed over large areas and is both bituminous and lignite. The coals of the former class are found in both tilted and flat seams, and of the latter in flat seams. The following are assays :—

	Moisture.	Volatile.	Carbon.	Ash.
Bituminous coals, Karagandy mine . . .	3·0	17·0	71·4	8·6
„ „ Kisiltav mine . . .	1·3	16·6	71·3	10·8
Lignite, Baiandi-Kuduk mine . . .	12·5	30·5	49·5	7·5

The bituminous coals belong to the Carboniferous period, and the lignites to a later series.

The coal seams of the Donetz basin are described by A. F. Stahl.¶

\* *Bollettino delle Finanze*, March 20, 1904; *Board of Trade Journal*, vol. xlv. p. 30.

† *Rassegna Mineraria*, vol. xx. pp. 145-148.

‡ *Geologisches Centralblatt*, vol. iv. p. 362.

§ *Moniteur des Intérêts Matériels*, vol. liv. p. 1055.

|| *Engineering and Mining Journal*, vol. lxxvi. pp. 731-733, 771-773.

¶ *Chemiker Zeitung*, vol. xxvii. p. 1147.

**Coal in Spain.**—A. Fabrega \* gives further details regarding the Utrillas coalfield.

L. Mallada † has prepared a lengthy monograph on the Sabero coalfield in Leon.

**Coal in India.**—P. N. Bose ‡ has discovered coal of good quality near Shillong in Assam. The most important seams are 4 and  $6\frac{1}{2}$  feet in thickness respectively. The coal deposits of the Mianwali district, Punjab, are described by R. R. Simpson.§ In the Punjab four groups of deposits were examined, which are distinguished as follows: (1) Kalabagh area, (2) Kuch area, (3) between Kuch and Sagruto summit, (4) Mulla Khel and Sultan Khel area. The Kalabagh deposits were found very variable in quality and thickness of workable seams, and the estimate of about 50,000 tons of available fuel is based on the assumption that an average thickness of 4 feet would be maintained over the strike of 550 feet. At Kuch, about six miles further north and less favourably situated for transport to the Indus, a rough estimate was made of 11,000 tons of available coal for a seam averaging about 16 inches in thickness. The coal seams opened by drives in the ground between Kuch and the Sagruto peak are not considered to be worth working. A more promising result was obtained in the Barochi gorge about two miles north of Mulla Khel; a seam, varying from 1 foot to 4 feet in thickness, was traced for about six miles to the south to a point west of Sultan Khel.

**Coal in Canada.**—E. Jacobs || describes and illustrates the coalfield of Crow's Nest Pass, British Columbia.

The coal deposits of Vancouver Island are described by W. M. Brewer.¶

**Coal in New South Wales.**—J. Dixon \*\* reports that driving is being continued at Sydney Harbour Collieries.

**Coal in Victoria.**—W. R. Anderson †† reports that the geological

\* *Revista Minera*, vol. liv. pp. 545-550.

† *Ibid.*, p. 568.

‡ *General Report of the Geological Survey of India*, 1903, p. 8.

§ *Ibid.*, p. 9.

|| *Engineering Magazine*, vol. xxvii. pp. 36-57, with fourteen illustrations.

¶ *Journal of the Canadian Mining Institute*, vol. vi. pp. 188-199.

\*\* *Annual Report of the Department of Mines, New South Wales*, 1902, p. 113.

†† *Annual Report of the Secretary for Mines and Water Supply, Victoria*, 1902, p. 6.

survey of the South Gippsland coal area is progressing rapidly. Beds of brown coal aggregating up to 120 feet in thickness have been found in the Laverton and Werribee plains, one being 33 feet 6 inches thick. Borings near Campbelltown show good results.

**Coal in Western Australia.**—H. S. King \* states that the Collie coalfield is still the only producing field in the state, and a 10-foot seam has been struck there. Boring operations are, however, being carried out near Mingenew, in the Irwin River District.

**Coal in South Africa.**—S. Michaelis † describes the coal deposits of the Transvaal.

**Coal in Asia Minor.**—M. Etienne ‡ gives the following analyses of coal from the Héraclée field :—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
1·16	31·64	60·56	6·62
0·80	28·73	64·06	6·41

**Coal in Bokhara.**—A list is given § of the principal coalfields in Bokhara, and the localities at which the coal is worked are briefly mentioned.

**Coal in the United States.**—A general account of the coalfields of the United States has been prepared by C. W. Hayes || for the United States Geological Survey. Among the reports issued by that body are papers on recent work in the bituminous coalfield of Pennsylvania by M. R. Campbell, ¶ and on recent work in the coalfield of Indiana and Illinois by M. L. Fuller and G. H. Ashley. \*\*

S. Cottier †† describes the principal coal deposits in the United States, giving a small map showing their relative position and the character of the coal obtained in the various localities. On account of the extreme regularity of the seams and the shallow depth at which

\* *Report of Department of Mines, Western Australia*, 1902, p. 8.

† *Finanz Chronik*, vol. ix. p. 473.

‡ *Annales des Mines*, vol. iv. p. 549.

§ *Iron and Coal Trades Review*, vol. lxviii. p. 320.

|| *United States Geological Survey, Bulletin No. 213*, pp. 257-269.

¶ *Ibid.*, p. 270.

\*\* *Ibid.*, p. 284.

†† *Publication de la Société des Ingénieurs de l'Ecole des Mines du Hainaut*, vol. xii. pp. 365-387.

they occur the work of winning the coal is greatly facilitated. A table is appended showing the rapid increase in output since 1865.

B. Simmersbach \* discusses the geological conditions of the northern region of the Appalachian coal basin in Pennsylvania and West Virginia.

**Coal in Alaska.**—A. J. Collier † describes the coal resources of the Yukon basin in Alaska. The seams vary from 1 to 5 feet in thickness and are much crushed. The coal varies from lignite to semi-bituminous and will only serve for local use. It occurs in sandstones of Eocene and Upper Cretaceous age.

**Coal in Colorado.**—A report on the Yampa coalfield of the Routt County, Colorado, on the projected line of the Denver, North-Western, and Pacific Railway Company (Moffat Road) has been drawn up by W. Weston. ‡ It shows that this coalfield covers an area of 900 square miles, with 75 feet of workable coal of good quality.

**Coal in Iowa.**—T. W. Beyer § and L. E. Young, in an account of the geology of Monroe County, Iowa, point out there are many important coal mines in the area, and the methods and extent of mining are treated in some detail. The coal beds are usually  $1\frac{1}{2}$  to 2 yards thick, and lie in a series of semi-distinct basins. The mines extend to a depth of 70 yards, the best and thickest coal being found near the base of the formation. It is bituminous and has an average of 47 per cent. of fixed carbon.

**Coal in Kansas.**—The stratigraphy and palæontology of the Upper Carboniferous rocks of the Kansas section are fully described by G. I. Adams, || G. H. Girty, and D. White. Their report summarises the available information, and clears up the synonymy of the stratigraphy.

**Coal in Montana.**—Some Montana coalfields are described by J. P. Rowe. ¶

\* *Zeitschrift für praktische Geologie*, vol. xi. pp. 413-423.

† *United States Geological Survey, Bulletin No. 218*, 71 pages.

‡ "The Yampa Coal Field on the Line of the Moffat Road," 1904.

§ *Iowa Geological Survey*, vol. xiii. pp. 355-422.

|| *United States Geological Survey, Bulletin No. 211*, 123 pages.

¶ *American Geologist*, vol. xxxii. pp. 369-380, with two maps.

**Coal in Virginia.**—H. W. Althouse\* describes the Norton coals of the Big Sandy Basin in Russell County, South-Western Virginia, and gives particulars of the various beds which range from 3 to 6 feet in thickness. J. T. Jennings† gives an account of the Henry colliery in West Virginia.

**Coal in Washington.**—H. Landes‡ and C. A. Ruddy describe the coal deposits in the Puget Sound basin and Cascade Mountains, Washington. They are of Eocene age and range from lignite to semi-anthracite. The beds are numerous and of good thickness but are much faulted.

**Coal in Mexico.**—It is stated§ that the coal of Las Esperanzas, Coahuila, Mexico, yields 67·7 per cent. of fixed carbon, 2·0 per cent. of moisture, 20·5 per cent. of volatile matter, and 9·8 per cent. of ash.

**Coal in Brazil.**—H. K. Scott|| in an account of the mineral resources of the state of Rio Grande do Sul, Brazil, refers to the carboniferous deposits of Sao Jeronymo and Candiota. At the first, the seam is 6½ feet in thickness and is mined pillar and stall. The coal is semi-bituminous and requires careful picking. The second deposit consists of a 7-foot seam with rather better, but more friable, coal.

L. F. Gonzaga de Campos¶ describes the coal beds of Tubarão, Santa Catharina, Brazil. He also describes\*\* the lignite deposits of Marahu, Bahia.

**Coal in Argentina.**—According to C. Vattier†† extensive coal deposits exist in the Argentine Republic, and they have now begun to be opened up.

**Coal in Peru.**—F. Alayza y Paz-Soldan‡‡ has prepared for the Peruvian government a report, covering 123 pages with three folding

\* *Engineering and Mining Journal*, vol. lxxvii. pp. 235-236.

† *Ibid.*, pp. 277-279.

‡ *Washington Geological Survey Annual Report*, 1902, vol. ii. pp. 165-277.

§ *El Minero Mexicano*, vol. xliv. p. 92.

|| *Transactions of the Institution of Mining Engineers*, vol. xxv. pp. 521-523.

¶ *Brazilian Mining Review*, vol. i. pp. 102-105.

\*\* *Ibid.*, pp. 124-129.

†† *Bulletin de la Société Scientifique Industrielle de Marseille*, vol. xxxi. pp. 13-52.

‡‡ *Boletín del Cuerpo de Ingenieros de Minas del Peru*, No. 3, Lima, 1903.

maps, on the mineral resources of the coast province of Moquegua and of the department of Tacna. Coal is met with in the districts of Carumas, Ichuña, Ubinas, Puquina, and Omate, and full particulars of its geological occurrence are given. In the first-mentioned district coal, anthracite, and lignite occur. Typical analyses of the three varieties are as follows :—

	Fixed Carbon.	Ash.	Volatile Matter.
Coal . . .	54·8	2·2	43·0
Anthracite . .	84·0	3·4	12·6
Lignite . . .	47·3	2·1	50·6

In Ichuña the coal deposits are extensive, and the quality at Pubaya is good. The Chaclaya coal contains a larger proportion of ash. The analysis yielded :—

	Fixed Carbon.	Ash.	Volatile Matter.
Chaclaya . . .	69·4	15·7	14·9
Pubaya . . .	77·1	8·3	14·6

**Coal in Honduras.**—A report \* by the United States Consul at Tegucigalpa states that the discovery of a large coal bed has been made in the mountains of the Department of Yoro, in Honduras. Tests of several samples of the coal taken from or near the surface establish the claim that it cokes with excellent result.

**Coal in China.**—V. Vandertaelen † has written a monograph on the Kaiping coalfield, China. The deposits extend from Lin-Se to Tongshan, about 60 miles, the beds, which number thirteen, varying in thickness up to 25 feet. The ash of the coal, which is otherwise a good bituminous kind, is somewhat high, and in some of the beds the sulphur rises to 2 per cent. The three principal shafts yield about 1,000,000 tons annually.

**Peat.**—C. E. Moss ‡ deals with the age, origin, and utilisation of the peat moors of the Pennines. Probably they originated in morasses resulting from the destruction of woods between Briton and Saxon times. Very little peat is cut in the district.

The Russian Department for trade, industry, and agriculture commissioned Wolff § to carry out experiments with peat fuel in Oldenburg.

\* *Globe*, December 1, 1903.

† *Annales des Mines de Belgique*, vol. ix. pp. 265-292.

‡ *Geographical Journal*, vol. xxiii. pp. 660-671.

§ *Mittheilungen des Vereins zur Beförderung des Gewerbfleisses*, 1903, pp. 295-350.

His report, which has now been published, relates to experiments with the Ziegler peat-coking process for the purpose of determining the value of peat coke as a fuel. The results are shown to have been favourable on the whole.

**Arsenic in Coal.**—The final report \* of the Royal Commission on Arsenical Poisoning has now been issued, and contains much information as to arsenic in fuel.

**Vanadium in Coal.**—J. C. H. Mingaye † gives analyses of the New South Wales coals containing vanadium. Coal from Leconfield colliery contained 0.02 to 0.12 per cent. of vanadic anhydride,

**Coal Storage under Water.**—J. Macaulay ‡ gives some observations on the subaqueous storage of steam coal, and gives some suggestions as to the cause of improvement as compared with storage in air.

### III.—CHARCOAL.

**Charcoal Kilns.**—E. A. Sjöstedt § describes the charcoal retort plant used by the Algoma Steel Company at Saulte Ste. Marie, Canada, in connection with blast-furnace plant. The retorts or ovens, of which there are twenty, are steel shells, 46 feet in length,  $6\frac{1}{4}$  feet wide, and  $8\frac{1}{2}$  feet high, with a double set of doors at each end. Low trucks, with skeleton frames, and running on a standard gauge track, hold two cords of wood each. Four of these trucks form one charge. The retorts are set in brick walls, and are heated externally from a grate at each end, the products of combustion passing off by a central chimney. The trucks stand in the oven for about twenty-four hours, and then are transferred to cooling chambers, of which there are two for each retort, each holding a charge for twenty-four hours. The truck-loads of charcoal are then taken direct to the blast-furnace or otherwise disposed of. Very little labour is required; the steam required for dealing with by-products from 300 cords of wood daily is generated in a 1500 horse-power boiler plant.

\* *Colliery Guardian*, vol. lxxxvi. p. 1295.

† *Records of the Geological Survey of New South Wales*, vol. vii. pp. 219-221.

‡ *Engineer*, vol. xcvi. pp. 415-416.

§ *Iron Age*, January 28, 1904, pp. 16-18.



O. Daube\* states that the residue from the Classen process of manufacturing alcohol from sawdust and waste wood is capable of being briquetted without binding material, and that the briquettes may be carbonised to produce charcoal and by-products.

Jürgensen† describes the recovery of by-products in charcoal-burning.

In an account of the manufacture of fuel and mineral briquettes, R. Schorr‡ deals with peat briquettes, and gives some particulars of the manufacture in Europe both of pressed and of carbonised blocks. Estimates of costs for plants with one and two machines are then given.

#### IV.—COKE.

**Beehive Coke.**—E. V. D'Invilliers§ compares the estimated cost of mining and coking, and the relative returns from operating in the Connellsville and Walston-Reynoldsville districts, Pennsylvania. Plants of 500 ovens are taken as the basis, with the average number of working days, and selling price at the ovens during five years. A summarised statement is given of the coal used and the coke produced under these circumstances. The average yield of coke from coal in the two districts is given as 67 and 57 per cent. respectively.

C. H. Hoyt|| gives some particulars of the deterioration of concrete in coke-oven foundations.

Illustrations are given¶ of the machine devised by J. A. Hebb for drawing coke from beehive ovens.

Some discussion has arisen\*\* on the question of 72-hour and 48-hour coke, and seems to show that it is somewhat difficult to differentiate between them.

**Improvements in Quenching Coke.**—When coke is drawn from the oven and water is thrown on it there is a loss of heat and of the gas resulting from the action of the water on the coke. It has,

\* *Iron Age*, September 17, 1903, p. 14.

† *Affärsvärlden*, vol. iv. p. 533.

‡ *Transactions of the American Institute of Mining Engineers*, February 1904.

§ *Ibid.*

|| *Engineering News*, vol. li. p. 107.

¶ *Mines and Minerals*, vol. xxiv. pp. 304-305; *Iron and Coal Trades Review*, vol. lxviii. p. 532; *Colliery Guardian*, vol. lxxxvii. p. 925.

\*\* *Iron Trade Review*, December 10, 1903, p. 55.

therefore, been proposed by Gobbe\* to quench the coke in an enclosed space, so as to collect the water-gas formed, and to enable it to be utilised for heat generation. A cylindrical form of gas-producer is employed, into which the red-hot coke is tipped, and there brought in contact with steam instead of water.

**By-Product Coke.**—In dealing with the modern types of coke-ovens P. J. Mallmann † states that the partisans of vertical flues are more numerous than those of horizontal flues. Otto, Hilgenstock, Coppée, Brunck, Poetter, and others advocated the vertical, whereas the Semet-Solvay was almost the only system where the horizontal position of the heating-flues was preferred; Collin adopted a combination of both. Pre-heating the air which was introduced into the heating-flues for the combustion of the gases was adopted in some ovens, when a regenerator was made use of for this purpose. The ovens were charged through openings in the roof of the coking-chambers, but when stamped coal was to be coked the oven was charged by charging-rams. The width of the oven is the most important factor as regards the duration of the coking period. The output per twenty-four hours varied from  $2\frac{1}{2}$  to  $4\frac{1}{2}$  tons of coke per oven, the amount of the output depending to some extent on the quality of the coal to be coked. W. Hawdon gave the output per oven per day at Newport at  $5\frac{3}{4}$  tons. The width of an oven was practically regulated by the quality of the coal used for coking.

A table is given of the dimensions generally adopted in retort ovens. The length ranges from 26 to 39 feet, the width from 16 to 24 inches, and the height from 4 to  $6\frac{1}{2}$  feet.

Modern coke oven plants and their working are considered by Göhrum.‡ He discusses briefly the various known forms of the coking process, dealing with them historically from the meiler to the coke oven arranged for the collection of the by-products. The development of the gas engine has directly affected the industry, the desire being to utilise in large gas engines poor and impure gas. This has been so far successful that poor coke-oven gas of the calorific power of from 2000 to 4500 calories per cubic metre can now be utilised in this way. The author shows that it is far more profitable for power raising purposes to collect the gas and tar and then to

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 686-687.

† Paper read before the Cleveland Institution of Engineers, April 18, 1904.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1205-1217, with four illustrations.

use the residual gas in gas engines, than to lose the by-products and burn the gas under a steam boiler. The author considers the utilisation of a coke-oven plant in connection with a central power station. In such a case an approximately definite excess of gas must be arranged for. In this connection, and from the point of view of best results generally, the coke-oven process is passed in review, the subject being dealt with calorimetrically. It is shown that in the older form of oven there was a very great loss of heat in the coke oven due to the use of cooling channels, fusion of the walls, &c., but this the modern oven, provided with heat regeneration arrangements, to a large extent eliminates. On the other hand, such methods of regeneration bring other evils in their train, as the author shows, the Otto-Hoffmann oven being criticised in this connection. The author has visited a number of coke-oven plants in Silesia, Moravia, and the district of the Saar. He found in these districts that the Otto-Hoffmann form of oven was the one principally employed. In considering these plants the author points out that the width of the oven has a great influence on the degree of rapidity of the coking process. The coal near the walls is coked first and then forms a sort of insulating partition keeping away the coal at the centre of the oven from the external source of heat, and the author gives as an example a Moravian work where the quantity of coal treated in the 24 hours in an oven, per cubic metre capacity, is 0.74 ton for an oven 0.40 metre wide in the clear, 0.68 ton for one 0.45 metre wide, and only 0.42 ton for one which is 0.675 metre in width, and this notwithstanding that the latter is provided with additional heating arrangements at the top. Analyses are given of the gases obtained from ovens at a number of works, and the use of the stamping machine for coking poorly-coking coals is described.

The author considers that (1) it is better to collect the by-products from coke ovens and to use the excess of gas in gas engines, rather than to burn them direct under steam boilers; (2) a satisfactory pre-heating system for the air for use in coke-oven plants, such as is needed for the proper development of the coke oven in connection with central power stations, is at present non-existent; (3) the gas engine can be used satisfactorily with any gas, no matter how poor it may be, so long as it can be made to explode in the cylinder of the gas engine. The author concludes by observing that the only satisfactory method so far found for coking coals that coke badly lies in the use of the stamping apparatus.

**Utilisation of Coke-Oven Gases.**—The economic utilisation of coke-oven gases for the heating of coke ovens and steam boilers, for driving gas motors, and for the supply of illuminating, heating, and power gas, is described by Ziebarth.\*

An exhaustive article has been published by Baum † on the utilisation of coke-oven gases for driving gas engines. Compared with the installations for using blast-furnace waste gases as motive power, the number of installations for the direct production of power from coke-oven gas is small. The oldest is the 12 horse-power motor at the Altenwald coke works. The installations of importance are of quite recent date. In the Saar coalfield at Neunkirchen a 200 horse-power motor has been at work since 1901. At the Minister Stein colliery there is a 125 horse-power engine, and a 350 horse-power engine at Lothringen colliery. In Upper Silesia there are two large coke gas-power plants, one at Beuthen with four Koerting motors of 300 horse-power each, and one at the Borsig works with a 600 horse-power motor. Particulars are given of fifteen motors, aggregating 4860 horse-power, driven by coke-oven gas.

The gas used for illuminating purposes has hitherto been produced from retorts of relatively small size. In recent years, however, the aim has been rather to produce a gas of great heating power than one by itself of high illuminating power. This has led to experimental changes in the method of distillation, and the results of experiments are now given in which a chamber resembling a coke oven in size, with a charge of 1 ton to 1·6 ton of coal, replaced the ordinary charge. The quantity of gas was about the same in both cases, but the products obtained from the Saar coal treated varied as is shown below :—

	Chamber Gas.	Retort Gas.
	Per cent. by vol.	Per cent. by vol.
Carbon dioxide . . . .	2·4	2·3
Heavy hydrocarbon . . .	2·5	4·5
Oxygen . . . . .	0·3	...
Carbon monoxide . . . .	9·1	8·6
Hydrogen . . . . .	52·8	49·4
Methane . . . . .	26·6	32·4
Nitrogen . . . . .	5·6	2·8
Totals . . . . .	99·3	100·0

\* *Zeitschrift des Oberschlesischen Vereins*, 1904, pp. 84-86.

† *Glückauf*, vol. xl. pp. 417-430.

The illuminating power was about 10 per cent. less, and the calorific power about 6 per cent. The latter is probably capable of improvement.\*

**A Modern Coke-Oven Plant and Coal-Compressing Machines.**—O. Simmersbach,† in discussing the charging appliances that are now adopted at modern coke-oven plants, gives an illustration of such a modern coal-washing and coke-oven plant in the Saar district of Germany. On the right lies the washing plant, on the left the coke ovens with a fine-coal tower above them, and between is the stamping and charging apparatus, railway tracks separating them from the coal-washing plant. The raw coal, about 2 inches in size, is brought in on these lines of rails, and tipped into a receptacle beneath them. This is divided into six chambers, each of which will hold 100 tons. This division enables six different kinds of coal to be stored at the same time. Beneath these again are belt conveyors which convey the coal to the washing plant, first being mixed together in such proportions as are desired in a mixing appliance, "mixing plates" on to which the coals are discharged being used for this purpose. From the washing plant the washed coal goes to disintegrators, and is ground, together with the slimes, to a size not exceeding 0.24 inch. The average ash contents is then 6 per cent. These disintegrators are placed high up, and discharge into the fine-coal tower, which is provided with four discharging funnels. This tower has a capacity of 300 tons. By another belt conveyor the fine coal is taken from this tower to the conveyor pits, which lie under the rails by the side of those used for raw coal. Thence the coal is raised by a bucket conveyor to a cylindrical iron receptacle used for storing the coal required for the coke ovens. This holds 1000 tons. This tower is placed in a central position between the batteries, each of which consists of sixty-five ovens, and is provided with one stamping and one charging machine. The tower discharges into waggons, which again discharge into the charging funnels of the stamping appliance, the feed of coal into this being regulated by a valve. As soon as the last portion of the coal has been charged into the stamping-box and compressed, the charging machine conveys the stamping apparatus to the ovens, the compression being actually completed while on the way. The

\* *Journal für Gasbeleuchtung und Wasserversorgung*, 1903, No. 32; *Stahl und Eisen*, vol. xxiii. pp. 1171-1172.

† *Stahl und Eisen*, vol. xxiii. pp. 1374-1378, with twelve illustrations.

compressed coal is charged into the oven and the whole run back again to receive a fresh charge of coal for compressing. The stamping machines that are in general use are illustrated and described, and the author deals in particular with that of Méguin, which he considers very satisfactory. By the use of such a Méguin compressing appliance, the output of coke ovens in the north of France has increased by 12·5 per cent. Another result, too, of the use of such compressors is that the coke smalls are reduced in quantity by one-half owing to the greater strength of the compressed coke. The loss of coal, too, in the oven is diminished, and the oven itself suffers less owing to the coal being compressed into shape before charging. Coal of a less coking power can also be employed.

**Coking Brown Coal.**—A. Semlitsch \* describes the conversion of brown coal into coke in the Zail Valley, Hungary. This occurrence of brown coal belongs to the Neogene formation, and the seams have been worked on a considerable scale in recent years. This brown coal is noticeable in that it is of a much better character than that which is usually found in Neogene beds. Not only is it of dense structure and high calorific power, but it also cakes well, and heated out of contact with air yields an excellent coke. Before, however, it became possible to make this coke commercially, a long series of experiments were necessary. It was first coked in meilers, but the coke so produced was useless for blast-furnace purposes. Next a coke-oven plant was erected, and further experiments made both there and elsewhere. The chief difficulty was that the resulting coke was very fragile and also very high in sulphur. The following are the results of one such test. The brown coal yielded :—

Water.	Volatile Constituents.	Fixed Carbon.	Ash.
2·74	41·04	47·62	8·60

The total sulphur amounted to 5·12 per cent., while the calorific power amounted to 6130 calories. Charged into a coke oven this fuel at first gave off such large quantities of gas that at first the temperature of the oven was lowered. However, this soon increased again and became higher and higher as the termination of the coking process was approached. The coke produced had caked well, had a good ring, and

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 133-137, 150-153, with plate; *Bányászati és Kohászati Lapok*, vol. xxxvii. pp. 469-483.

showed the usual pyramidal structure. When water was thrown on the hot coke there was a very considerable evolution of sulphur dioxide and hydrogen sulphide. Assay showed the coke to contain 4.33 per cent. of sulphur, 0.0082 of phosphorus, and 12.78 per cent. of ash. The results of other similar tests are given. In one case it was pointed out that it was necessary to wet the brown coal before coking it in order to make it cake better, but the upper part of the coke mass was then less well caked than the lower part.

These earlier and unsuccessful experiments were followed by a lengthened pause, but then R. Hoffmann took them up again, and had a considerable quantity of the fuel coked by an Upper Silesian company. It contained 9.02 per cent. of ash, and the ash-free material consisted of:—

Carbon.	Hydrogen.	Nitrogen.	Oxygen.
76.28	5.35	1.48	16.89

The total sulphur amounted to 3.47 per cent., the volatile sulphur amounting to 1.54 per cent., and the non-volatile to 1.93. In the crucible this fuel yielded 60.31 per cent. of coke, containing 3.19 per cent. of sulphur and 15.54 per cent. of ash.

In the coke oven there was produced per ton of the fuel coked 436 cubic metres of gas at 15° C. The ammonia amounted to 0.515 per cent., the tar to 4.75, and the coke to 62.54. The quality of the coke was, however, not very good. Still this experiment led to a small coke-oven plant being erected in 1899, and another followed, which is described and illustrated.

The coke ovens used are described. Each is 33 feet 7 inches long, 1 foot 9 inches and 1 foot 10 inches wide, and 5 feet 10 inches high. There are thirty of them, each taking a charge of 7 tons of the dry washed and stamped small coal. The yield from this dry coal consists of 51.39 per cent. of lump coke, 7.07 per cent. of medium coke, 2.25 per cent. of nuts, and 3.18 per cent. of smalls and dust. An electrically-driven discharging machine is employed. From forty-two to forty-four hours are required for the coking, and altogether the plant can make 31,000 tons of coke a year. The ovens are not at present arranged for the collection of the by-products, but this can be easily provided for. At first the brown-coal was only washed and not stamped, but though the coke produced was lustrous and hard, it was brittle and broke up too much during transport. The average of the assay results of seven samples of coke shows 17.88 per cent. of moisture and 10.63 per cent.

of ash, whilst the sulphur calculated on the dry material was 2·88 per cent. The ash of the coke contained per cent. :—

SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	CaO.	MgO.	Fe.	Mn.	S.
34·50	19·38	10·54	4·26	19·53	0·52	5·33

This coke was tried in a small blast-furnace using calcined residues containing 0·035 to 0·015 per cent. of sulphur, and 2·72 to 1·08 per cent. of manganese. Three Cowper stoves gave blast at a temperature of 550° to 600°, and the furnace made about 32 to 33 tons of grey iron in the twenty-four hours. The quantity of brown-coal coke was gradually increased until it amounted to 40 per cent. of the whole amount of coke used, the irons produced containing :—

Carbon.	Silicon.	Manganese.	Sulphur.
3·19 to 3·52	0·72 to 1·95	1·45 to 2·67	0·025 to 0·040

When the brown-coal coke was increased to 60 per cent. of the total, the carbon, manganese, and silicon contents decreased, while the sulphur contents became too high. The method of working the blast-furnace was modified, and then, with the same fuel mixture, good results were again obtained. The coke used averaged 0·998 per cent. of sulphur, yet the iron made contained only from 0·010 to 0·045. Of fifteen samples only one showed above 0·04, four contained 0·040, one contained 0·028, one 0·025, and the remainder were all below this in sulphur contents. The other chief constituents varied as follows :—

Carbon.	Silicon.	Manganese.
3·52 to 4·03	0·65 to 2·15	1·59 to 3·32

A number of other partial analyses of pig irons and slags made are also given. The furnace worked steadily, but the charges were kept more basic, and less ore was used as compared with the coke, but the cheap price of the latter made up for this.

The distillation of Bohemian brown coal is described by R. Hodurek.\*

**German and Austrian Cokes.**—A. Semlitsch† states that the Prussian and Austrian cokes in use at a blast-furnace at Kaláu in Hungary contained per cent.: Prussian coke, moisture 9·11 per cent., ash 8·14 per cent., and sulphur in the dry substance 0·89 per cent., this being the average of six samples. Austrian coke, moisture 11·30 per cent., ash 11·30 per cent., sulphur in the dry material 1·16

\* *Chemiker Zeitung*, vol. xxviii. p. 273.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 151.



per cent., this being the average of the assays from nine samples. Upper Silesian coke used at the same furnace contains :—

Ash.	Volatile Matter.	Sulphur.	Moisture.
9.57	3.71	1.48	8.0

and its ash consisted of :—

SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	CaO.	MgO.	Fe <sub>2</sub> O <sub>3</sub> .	Mn.	P.	S.
18.86	14.06	16.79	7.37	31.39	0.74	0.097	6.36

The coke produced from the coal raised by the Witkowitz collieries in Moravian-Ostrau contains on the average 0.75 per cent. of sulphur. The sulphur contents of Westphalian coke averages 1.1; in samples of Ostrau coke other than from the Witkowitz mines, 1.4 to 2.0 per cent. is met with, and coke samples from the Waldenburg section of the Upper Silesian field contain about 1.8 per cent. \*

## V.—LIQUID FUEL.

**Origin of Petroleum.**—L. Demaret † discusses the origin of petroleum, and the geological conditions of its occurrence. The methods of winning the oil and its preparation are dealt with, and numerous illustrations accompany the article.

Recent progress in the investigation of the chemistry of petroleum is described by D. Holde ‡ and by R. Kissling.§

**Petroleum in Austria.**—L. Szajnoch|| discusses the origin of the petroleum of Wojcza in Galicia.

M. Wietezynski ¶ describes the petroleum fields of Mraznica in Galicia.

The geology of the petroleum zone of Opaka-Schodnica-Urycz, in East Galicia, is described by R. Zuber.\*\*

Mentzel †† describes the Schodnica oilfield.

\* *Stahl und Eisen*, vol. xxiv. pp. 297-298.

† *Annales des Travaux Publics de Belgique*, October 1903.

‡ *Chemische Zeitschrift*, vol. iii. pp. 233-237.

§ *Chemiker Zeitung*, vol. xxviii. pp. 541-543.

|| *Kosmos* (Lemberg), vol. xxvii. pp. 299-319 (in Polish).

¶ *Moniteur du Pétrole Roumain*, vol. v. p. 109.

\*\* *Zeitschrift für praktische Geologie*, vol. xii. pp. 86-94; *Moniteur du Pétrole Roumain*, vol. v. pp. 245-249.

†† *Glückauf*, vol. xxxix. pp. 1101-1110.

R. Zuber \* discusses the geology of Boryslav oilfields in Galicia, and gives sections of the petroleum- and ozokerite-bearing strata.

C. Angerman † describes the geology of the Boryslav deposits.

Mentzel ‡ gives a detailed account of the visit to the Boryslav ozokerite mines. The output in 1902 comprised 2560 tons of ozokerite and 335,410 tons of petroleum.

The report of an official commission appointed by the Austro-Hungarian Ministry for Agriculture has now been published. This deals with the ozokerite mines of Galicia. This commission was appointed on account of an explosion which took place in the summer of 1902. The ozokerite occurs in veins of varying thickness in the Miocene formation in clays, or between clays and slates. The width varies up to more than 200 yards. The whole subject of the occurrence and mining of these ozokerite deposits is dealt with in the report at much length.§

J. Holobek || describes a firedamp explosion that occurred on June 2, 1902, at the ozokerite mines at Boryslav. It resulted in the deaths of sixteen of the workmen, whilst four others were severely injured. The workings are described. The gas met with in the workings consists chiefly of methane, and considerable quantities have to be dealt with. The average of eight analyses made of the air after passing through the workings, during the period from January to the end of April preceding the explosion, showed 0·52 per cent. of hydrocarbons, the minimum percentage observed having been 0·23 and the maximum 0·75. Shortly before the explosion took place the ventilating fans had ceased to work for a time. The effects of the explosion are described, and as the explosion started in the vicinity of the electric motors driving the fans it might have been supposed that these electric arrangements were at fault. This does not appear to have been the case, however. It would rather seem that a lighted Müsseler lamp was placed too near the fan, and that the draught from it had caused the flame to blow through and so exploded gas around the lamp.

\* *Zeitschrift für praktische Geologie*, vol. xii. pp. 41-48; *Oesterreichische Chemiker und Techniker Zeitung*, 1904, No. 9.

† *Ungar. Montan Ind. und Handelszeitung*, 1904, No. 2.

‡ *Glückauf*, vol. xxxix. pp. 1073-1085.

§ *Ergebnisse der vom k.k. Ackerbauministerium im Jahre 1902 eingesetzten Kommission zur Untersuchung der Betriebsverhältnisse des Erdwachsbergbaues in Galizien*, Vienna, 1903; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 585-586.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 41-45, 55-59. 1904.—i.

**Petroleum in Germany.**—Details are given by L. Müffelman\* of the petroleum undertakings in Germany. Petroleum is produced in small quantities in Bavaria, Alsace, and Hanover. Altogether there are twenty-two petroleum companies in operation.

The occurrence of petroleum in Westphalia is described by G. Müller.†

**Petroleum in Italy.**—Analyses of Italian petroleum are given by L. Balbiano ‡ and P. Zeppa.

**Petroleum in Roumania.**—J. M. Gottlieb§ describes the occurrence and extraction of petroleum in Roumania.

**Petroleum in Russia.**—An account has been published || of the new discoveries of petroleum in Tiflis. At Chatma rich deposits have been found at a depth of 360 feet, and the price of land at that locality is rapidly rising.

E. D. Levat ¶ describes the occurrence of petroleum in Turkestan.

K. W. Charitschkoff\*\* describes the carbonaceous substances accompanying petroleum at Grosny and at Chatma in the Caucasus. It is suggested that the coal is a product of the alteration of the petroleum.

**Petroleum in Spain.**—Joaquin Alio †† describes the occurrence of petroleum at Baga and Broca in the province of Barcelona.

**Petroleum in Trinidad.**—Analyses of petroleum from Trinidad made at the Imperial Institute ‡‡ show that the oil discovered at Guayaguayare is of commercial value.

**Petroleum in Albania.**—A. Gounot§§ describes the bitumen mines worked in the vilayet of Janina.

**Petroleum near the Bagdad Railway.**—According to P. Rohr-

\* *Moniteur du Pétrole Roumain*, vol. v. p. 214.

† *Zeitschrift für praktische Geologie*, vol. xii. pp. 9-11.

‡ *Gazzetta*, vol. xxxiii. pp. 42-50.

§ *Berg- und Hüttenmännische Zeitung*, vol. lxii. pp. 517-519.

|| *Moniteur du Pétrole Roumain*, vol. v. p. 217.

¶ *Journal du Pétrole*, 1903, Nos. 15 and 16.

\*\* *Journal of the Russian Chemical Society*, vol. xxxv. pp. 695-701.

†† *Gaceta Minera de Cataluña*, vol. iii. p. 1276.

‡‡ *Imperial Institute, Bulletin* No. 4, p. 177.

§§ *Annales des Mines*, vol. iv. pp. 5-23.

bach \* a broad zone, lying between the Persian frontier mountains in the region of the Lower Sab and stretching in a south-westerly direction over the Tigris and Euphrates into the Arabian Desert, including Kerkuk, Tekrit (on the Tigris), and Hit (on the Euphrates), appears to be full of bitumen, petroleum, and carburetted hydrogen. The inflammable gases exuding near Baba Gurgur and the oil-wells at Kerkuk are more abundant than those in Russian Transcaucasia, on the Apscheron Peninsula, before borings were begun. The importance of this fact will be evident when the Bagdad Railway passes through the district close to rich petroleum wells. This petroleum supply will be all the more important for the Bagdad Railway, seeing that the supply of coal along the line, as far as yet explored, appears to be considerable.

**Petroleum in Canada.**—A report on the principal petroleum resources of Canada has been published.†

**Petroleum in India.**—R. D. Oldham ‡ has traced the course of the anticline running northwards from the Yenangyat oil-field. Regarding the investigation of a possible oil-field near Pakoku district, Upper Burma, northward, it is stated that the structure is that of a productive oil-field, and it is possible that a remunerative supply of oil could be obtained, although, owing to the formation, the oil will not be obtainable at the pressure which gives rise to the flowing wells of Yenangyat.

**Petroleum in the United States.**—A number of papers on oil and asphalt fields are presented by the United States Geological Survey. A paper on the origin and distribution of bituminous deposits by G. H. Eldridge§ serves as an introduction. Other papers are on the petroleum fields of California, by G. H. Eldridge;|| on the Boulder oil-field, Colorado, by N. M. Fenneman;¶ on asphalt and oil in south-western Indiana, by M. L. Fuller; \*\* on structural work in the eastern Ohio oil-field, by W. T. Griswold; †† on the oil-fields of the Texas-Louisiana Gulf Coastal Plain, by C. W. Hayes; ‡‡ and on the asphalt deposits of Pike county, Arkansas, by C. W. Hayes.§§

\* *Zeitschrift für praktische Geologie*, vol. xi. p. 455.

† *Imperial Institute, Bulletin* No. 4, pp. 183-187.

‡ *General Report of the Geological Survey of India*, 1903, p. 14.

§ *United States Geological Survey, Bulletin* No. 213, p. 296.

|| *Ibid.*, p. 306.

¶ *Ibid.*, p. 322.

\*\* *Ibid.*, p. 333.

†† *Ibid.*, p. 336.

‡‡ *Ibid.*, p. 345.

§§ *Ibid.*, p. 353.

**Petroleum in California.**—C. E. Heurteau\* has published a report on the present condition of the petroleum industry in California. The geology of the petroleum-bearing region is described, sections being shown of the strata in the neighbourhood of the following chief centres of production: Puente Hills, Los Angeles, Ventura, Summerland, Kern River, Mackittrick, Sunset, and Coalinga. The most important of these centres, as regards output, is Kern River, which was first opened up in 1899, and in that year yielded 15,000 barrels. In 1902 there were 322 wells in active operation of a depth varying from 50 to 145 yards, from which 8,648,109 barrels were obtained, the total production of all the Californian fields being 13,692,514 barrels in the same year. In character the Californian petroleum is essentially heavy, and in this respect differs considerably from the oils of Pennsylvania and Baku. The mean density for the former is 0·96, while that of the oil from the other two great centres is 0·80 and 0·85 respectively. The composition shows a high percentage of carbon :—

	C.	H.	O.	N.	S.
Los Angeles . . .	86·9	11·8	...	1·10	...
Ventura . . .	84·0	12·7	1·2	1·7	0·4

It is chiefly used as a fuel, for which its qualities render it highly suitable.

**Petroleum in Colorado.**—W. Weston† has prepared a report on the hydrocarbon deposits on the projected line of the Denver, North-Western, and Pacific Railway Companies. Where the coals end the hydrocarbons begin, and thus give a carbonaceous produce for 200 miles along the railway. Petroleum is worked at Raven Park, Colorado. Asphalt deposits extend westward to Pariette, Utah, and there are then elaterite deposits in Indian, Lake, and Sams cañons. The total hydrocarbon area is about 10,000 square miles.

**Petroleum in Idaho.**—In a report on the geology of south-western Idaho and south-eastern Oregon, Israel C. Russell‡ states that the southern part of Canyon county is the only locality in western Idaho in which boring for petroleum is justified. In order to obviate fruitless attempts to discover petroleum, he gives a statement of the general principles bearing upon the occurrence of petroleum.

\* *Annales des Mines*, vol. iv. pp. 215-249.

† "The Hydrocarbons on the Line of the Moffat Road," 1904.

‡ *United States Geological Survey, Bulletin No. 217*, 83 pages.

**Petroleum in Kansas.**—According to G. P. Grimsley,\* the vicinity of Iola has become of great importance owing to the development of a gas-field. The gas reservoir is a porous sand 20 to 150 feet thick in lower coal measure shales. Most of the wells are 815 to 920 feet deep, and the pressure is 315 lbs. per square inch. J. A. Yates† describes the gas-well at Ottawa, Kansas. The gas sand was struck at a depth of 420 to 1125 feet.

**Petroleum in Missouri.**—G. C. Broadhead‡ discusses the theories regarding oil formation with special reference to the bituminous rocks of Missouri.

**Petroleum in Texas-Louisiana.**—C. W. Hayes§ and W. Kennedy have completed their report, covering 174 pages, upon the oil-fields of the Texas-Louisiana Gulf Coastal plain. The various deposits of sands, clays, and sandstones were examined and compared, their continuity across the country was traced, their geologic conditions were studied, and their position in the general section of the region was worked out. In addition, the logs of the various deep wells throughout the whole Coastal plain were gathered, as far as possible, and the results of the borings collated and compared. By these means the general underground conditions of the region, to a depth of about 2000 feet, have been determined. With regard to the origin of petroleum, the numerous different theories advocated by geologists are classified and divided into three main groups: (1) Those which explain the origin of oil as due to inorganic agencies; (2) those which ascribe it to an organic origin; and (3) those which involve both inorganic and organic agencies. After considering the diversity of theories, the conditions for accumulation of oil are enumerated, and the authors then deal with the physical and chemical properties of the oil of this region. Its specific gravity ranges from 0.904 to 0.925, which is much higher than that of petroleum from other well-known fields containing a notable proportion of illuminants, and its flashing point is correspondingly higher. The Gulf Coast oil does not, however, appear to be adapted to the production of illuminating oil by any refining processes at present known, but its calorific value com

\* *Transactions of the Kansas Academy of Sciences*, vol. xviii. pp. 78-82.

† *Ibid.*, pp. 106-108.

‡ *American Geologist*, vol. xxxiii. pp. 27-35.

§ *The United States Geological Survey, Bulletin No. 212*, 174 pages.

parens favourably with that of the best liquid fuels known. Some comparative tests with locomotives show that it is chiefly to be valued on account of its suitability for oil-firing. The method of burning the oil is illustrated and described, its storage and transportation are considered, and, in conclusion, the methods of well-drilling and various types of drills are illustrated and discussed.

D. A. Willey \* writes on the Texas oil industry and its present position. A period of steady production and legitimate business appears to have set in.

The hydrocarbons forming the main constituents of Louisiana petroleum have been determined by C. E. Coates † and A. Best.

**Petroleum in Peru.**—F. O. Lopez ‡ describes the occurrence of petroleum in Parta, Peru.

**Oil Shale.**—J. B. Sneddon § describes the Duddingston shale mines and the Niddrie Castle crude oil works.

A monograph by J. E. Carne || has been published by the Geological Survey of New South Wales, and gives a complete summary of the character, origin, occurrence, and utilisation of oil shales in that county. It occupies 333 pages and contains numerous illustrations and maps.

In a report ¶ by W. H. Twelvetrees, Government geologist, some interesting details are given of the kerosene shale or cannel coal seams owned by the North-West Coal and Shale Company, at Preolenus, Tasmania. The entire thickness of the beds in which the various seams are located appears to be about 800 feet, but the main seams are restricted to a band of sandstone from 80 to 100 feet thick.

**Asphalt.**—V. Novarese \*\* gives a detailed description of the asphalt deposits of San Valentino in Abruzzo. The mines are situate in the Majella range in the province of Chieti, and are distant about 20 miles from the open roadstead of Pescara on the Adriatic. The

\* *North American Review*, January 1904.

† *Journal of the American Chemical Society*, vol. xxv. pp. 1153-1158.

‡ *Boletín del Ministerio de Fomento*, vol. i. p. 16.

§ *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 122-133.

|| "The Kerosene Shale Deposits of New South Wales," 1903.

¶ *Iron and Coal Trades Review*, vol. lxvii. p. 1009.

\*\* *Rassegna Mineraria*, vol. xx. pp. 1-4.

Majella mountains belong to the Tertiary horizon. Lower Miocene and Eocene beds are strongly developed, and are represented by conglomerates, gypsum, grey clays, limestone, and marls. The beds vary in thickness from some 20 to 100 yards, the total formation reaching a thickness of over 1000. The limestones are often bituminous, the percentage of bitumen being variable. The asphaltic beds are found over an area of some 15 or 20 square miles, the bedding agreeing on the whole with that of the adjacent rocks. Three parallel asphaltic zones may be distinguished differing in petrographical character. The asphalt deposits have but little overburden, and in some cases they actually come to surface. Analyses are given of the asphaltic limestone from six different mines, the highest and lowest bitumen percentages being shown in the two following cases:—

	Acquafredda.	Cusano.
	Per Cent.	Per Cent.
Bitumen . . . . .	10·62	15·70
Insoluble silica . . . . .	0·30	0·48
Soluble silica . . . . .	traces	traces
Calcium carbonate . . . . .	86·40	49·70
Magnesium carbonate . . . . .	1·50	32·00
Ferric oxide and alumina . . . . .	0·52	0·32
Moisture and volatile products at 100° . . . . .	0·66	0·98
Totals . . . . .	100·00	99·18

The rock of the San Giorgio, another of the mines, is particularly rich in asphalt. In places this varies from 9 to 30 per cent., the rock being completely permeated by bitumen. Indeed, at times it is so completely saturated that the heat of the sun is enough to cause the bitumen to exude. In all the mines the asphaltic rock is a dolomitic limestone with only traces of quartz or silicates. The various mines are described. The asphalt extraction works possesses two large asphalt mills, each of which is capable of grinding 4 tons of rock to a fine state per hour. Each mill averages about 150 tons per working day. There are also six large boilers provided with stirrers which average from 50 to 80 tons per day as their output, and a refinery is also attached to the works. Electricity is employed as the motive power for the whole work. The mines yielded an output of 12,000 tons in 1902, that of the works amounting to 11,000 tons.



J. Nieszner\* describes the asphalt deposits of Dalmatia, with special reference to the occurrence at Vergoraz.

In Palestine bituminous or asphaltic limestones occur in enormous quantities along a belt parallel to the Dead Sea and the Jordan valley. At Nebi Musa, according to M. Blanckenhorn,† the percentage of bitumen in the rock attains a maximum of 25. The mineral appears to be suitable for street-paving purposes. The asphalt of the Dead Sea region fetches high prices, but no systematic working of it on a large scale has yet been attempted.

H. Louis‡ describes the asphalt deposits of Trinidad, the production of which has increased from 9000 tons in 1873 to 165,000 tons in 1902. The memoir is illustrated by a chart of the island of Trinidad, a map of Pitch Lake, and photographic views.

An analysis of natural pitch or manjak from Trinidad § yielded

Fixed Carbon.	Volatile Matter.	Ash.	Moisture.
55.15	40.92	3.55	0.38

A. Lakes|| gives some interesting illustrations of the workings in a gilsonite or asphaltine vein at Fort Duchesne. The vein is about 3 feet wide, and is worked by daylight to a depth of about 90 feet by underhand stoping. One illustration shows a timbered trench extending to the horizon.

F. H. Minard¶ describes the production of asphalt from crude oil in California. The oil is distilled in closed stills through which air is blown, and the heat is run up to 650° F.

W. R. Crane\*\* deals with asphalt mining and refining in Indian Territory. The Tar Springs deposit, the method of drilling for prospecting by water flush and churn drills, the geology and character of the asphalt, and the methods of mining and refining are briefly described.

G. Lunge†† and V. Krepelka give the results of an exhaustive investigation of asphalt.

D. A. Sutherland‡‡ discusses the definition of the term bitumen.

\* *Montan Zeitung*, vol. xi. p. 163.

† *Zeitschrift für praktische Geologie*, vol. xi. pp. 294-298.

‡ *Public Works*, vol. ii. pp. 230-238.

§ *Bulletin of the Imperial Institute*, No. 4, pp. 180-182.

|| *Mines and Minerals*, vol. xxiv. pp. 135-136.

¶ *Engineering and Mining Journal*, vol. lxxvi. pp. 503-505.

\*\* *Ibid.*, pp. 926-928.

†† *Chemiker Zeitung*, vol. xxviii. pp. 177-180.

‡‡ *Electro Chemist and Metallurgist*, vol. iii. pp. 322-335.

He enumerates the sources of supply, and considers the physical and chemical characteristics of bitumen, with special reference to Trinidad bitumen. The latter half of the paper deals with the uses of bitumen for electrical purposes.

**Boring for Petroleum.**—V. Tacit\* describes the Canadian system of boring, and A. Braesco† describes the Pennsylvanian system of rope-boring as practised in Roumania.

A novel method of perforating the casing of an 8-inch well has been adopted in a water-well at Fort Worth, Texas. A "cannon" made of a bored piece of steel shafting was lowered in the well and used to shoot a pointed projectile through the casing at depths of from 150 to 800 feet. A charge of  $\frac{1}{2}$  to  $\frac{3}{4}$  oz. of dynamite was used for each shot.‡

L. Gaster§ describes the application of electricity in oil-fields for driving machinery.

**Oil Fuel Burners.**—J. S. V. Bickford|| describes various forms of liquid fuel burners, dividing them into two classes according as the fuel is vaporised before or simultaneously with combustion.

**The Use of Liquid Fuel.**—Polster¶ recommends the use of petroleum as a binding agent in the manufacture of coal-briquettes.

## VI.—NATURAL GAS.

**Natural Gas in South Germany.**—Traces of petroleum have been found between Carlsruhe and Heidelberg in Baden. C. Engler\*\* states that two boreholes that have been put down have shown small quantities of oil, and natural gas has also been struck. Indeed, one borehole sunk near Büchelberg in 1890 yielded considerable quantities of a gas which contained, by volume: Methane, 79·6 per cent.; ethane, 3·7 per cent.; oxygen, 2·3 per cent.; and nitrogen, 14·4 per cent.

\* *Moniteur du Pétrole Roumain*, vol. v. pp. 77-79.

† *Ibid.*, vol. v. pp. 80-81.

‡ *Engineering News*, vol. li. p. 50.

§ *Electrical Magazine*, February 1904.

|| *Engineering*, vol. lxxvii. p. 523.

¶ *Allgemeine oesterreichische Chemische und Technische Zeitung*, October 15, 1903, pp. 3-4.

\*\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. p. 630.

**Natural Gas in Austria.**—The occurrence of natural gas at Wels in Upper Austria is described by O. Stephani.\*

**Natural Gas in Kansas.**—Particulars are given by G. P. Grimsley † in an officially issued pamphlet of the oil, gas, and other industries of Kansas. The oil and gas are found in the nine counties in the south-eastern portion of the state running southward into Indian territory.

## VII.—ARTIFICIAL GAS.

**Thermal Reactions in the Gas Producer.**—In connection with the paper on the thermal reactions of the gas producer by F. W. Lürmann, jun., ‡ a correspondence has ensued, K. Kroeker § contending that the author based his calculations on wrong assumptions, the analyses of the gas coal given and of the volatile products of distillation being both, he contends, inaccurate. A number of other matters are also disputed. To this the author of the original paper replies.||

**Gas Producers.**—An illustration is given ¶ of the Duff gas producers at W. Beardmore & Co.'s works at Dalmuir for supplying gas engines of 8000 horse-power.

H. Brauns \*\* describes and illustrates the Duff system of gas producers. The first of these plants was erected at the works of the United Alkali Company at Fleetwood in 1893, and since then experience has led to considerable improvements. As now constructed all kinds of fine coal may be employed, even if of a bituminous character, and lump coal may be employed that contains from 10 per cent. to 24 per cent. of ash. The producer admits of the collection of ammonium sulphate, and about 0·035 to 0·050 ton of this is collected for every ton of coal that is passed through the producers. British coal, containing 1·25 per cent. of nitrogen, yields 0·045 ton of the sulphate. The largest of these plants that have yet been constructed are at the works of

\* *Zeitschrift für angewandte Chemie*, vol. xvi. pp. 27–32.

† "Oil Gas and Glass, Chemical Industries and Minerals of Kansas"; *Iron Age*. November 5, 1903, p. 15.

‡ *Journal of the Iron and Steel Institute*, 1903, No. II. p. 582.

§ *Stahl und Eisen*, vol. xxiii. pp. 1151–1154.

|| *Ibid.*, pp. 1154–1155.

¶ *Engineer*, vol. xcvi. p. 370.

\*\* *Stahl und Eisen*, vol. xxiii. pp. 1191–1196, with five illustrations.

Sir W. G. Armstrong, Whitworth & Co. Ltd., and at the Parkhead Steelworks, Glasgow, each of which gasifies 200 tons of coal a day in ten producers, further details of which are given.

Illustrations are given \* of Crossley's gas producers, designed especially for gas engines.

Illustrations are given † of Pierson's gas producer, in which the gas is drawn away by a suction pump through scrubbers.

J. Langton ‡ describes the power plant of the Moctezuma Copper Company at Nacozari, Sonora, Mexico, where gas engines driven by producer gas are used for driving dynamos. Loomis-Pettibone water-gas producers are used with exhausting blowers of the Roots type for drawing off the gas from the producers through scrubbers. The producers are of the down-draught type, and are fired with coal or wood. Details are given of the method of making gas from wood, § steam not being then required. Analyses of the gas and various logs of different runs are given.

J. Deschamps || has designed a gas producer in which the combustion of the fuel takes place in a reverse direction, that is, from the top of the fuel bed downwards. The apparatus consists of a cylindrical iron casing, lined for over two-thirds of its height with a thick refractory lining. Resting upon this is a cast-iron hopper, which occupies the remaining space in the casing and forms the upper end of the combustion chamber. The hopper is covered with a flat plate, provided with openings through which the coal is fed. The fuel is charged into the hopper, and descends through the chamber, filling it completely. The bottom of the chamber is formed by a sloping grid, beneath which is the ashpit. The gaseous products escape through an opening just above the lower end of the grid into an adjoining vertical cylindrical receiver, into which they rise and pass off through openings near the top. This second chamber is fitted with a long spiral coil of iron tubing, through which the air necessary for combustion is circulated, being drawn in by natural draught. The air enters at the upper end, and after descending to the lowermost coil, it is led through an upright pipe into a tuyere projecting vertically downwards into the upper layers of fuel in the hopper, and terminating at the point where the refractory lining begins. The air becomes highly pre-heated owing to

\* *Engineer*, vol. xcvi. pp. 578-580.

† *Engineering*, vol. lxxvi. p. 696.

‡ *Transactions of the American Institute of Mining Engineers*, October 1903.

§ *Journal of the Iron and Steel Institute*, 1899, No. II. p. 365, 1902, No. I. p. 287.

|| *Bulletin de la Société de l'Industrie Minérale*, vol. ii. pp. 889-918.

the contact of the hot volatilised products with the spiral tube, and it thus aids the combustion in the mass of fuel which is ignited at the zone where the tuyere terminates. It is claimed that by this means a stable producer gas can be generated from coal richer in volatile constituents than that usually employed, and that without the aid of steam a gas of high calorific power can be obtained.

In Whitfield's gas producer coke is used as the fuel, and the rise and fall of the holder regulates the air and steam supply automatically. Sections of the plant are given.\* Further articles on anthracite gas producers for power purposes describe Bénier's producer, the Taylor plant, Crossley's producer, Bowman's producer, the Winterthur producer, Pierson's producer, Tangyes' producer, the Pintsch producer, the Bollinckx producer, the Deutz producer, and Körting's producers, working by suction and by pressure.

K. Bräuer† has carried out a series of investigations with a gas producer working on the suction principle. The chief economical advantage of this type of producer is that the steam-boiler is done away with, and the steam for mixing with the fuel is generated solely by the waste heat of the gases and the radiant heat of the producer itself. The author gives a large number of intricate calculations to determine the efficiency of the plant, and expresses the opinion that the producer-gas engine of to-day is still susceptible of a number of improvements.

Barkow‡ also discusses gas produced in suction generators, and the types of engine used in combination with these installations.

**Water-Gas.**—O. Nagel§ deals shortly with the chemical and metallurgical future of water-gas, which under the Dellwik-Fleischer system has recently come into considerable use.

A paper on water-gas was read before the Association of Austrian Engineers by H. Jüptner von Jonstorff,|| and an interesting discussion subsequently ensued. Görlitzer pointed out that the urban authority of Vienna is erecting a water-gas plant which is to yield 3,500,000 cubic feet of gas a day. This is to be made illuminating by the use of

\* *Iron and Coal Trades Review*, vol. lxvii. pp. 1349, 1421, 1491, 1565, 1632, 1846; vol. lxviii. pp. 107, 310, 599.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1517-1524.

‡ *Mittheilungen aus der Praxis des Dampfkessel-Betriebes*, 1903, pp. 768-770.

§ *Engineering and Mining Journal*, vol. lxxvi. p. 617.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. Beilage No. III. pp. 15-17.

oil, and is to be used in addition to the ordinary coal-gas plant for illuminating purposes. In Germany the high price of the carburising oil has led to attempts to use it direct or when saturated with benzene. Its use for welding and similar purposes was also referred to, and it was pointed out that at the Julius Pintsch works at Fürstenwalde the producer-gas obtained in the manufacture of the water-gas is used to drive a 300 horse-power gas-engine plant. Other speakers also took part in the discussion.

H. Steger \* has published an article on water-gas with special reference to the process of Kramers and Clarts.

V. Lewes † estimates the calorific value and lighting power of coal-gas and carburised water-gas.

**Mond Gas.**—Plans, sections, and illustrations are given ‡ of the Mond gas plant used for driving rolling-mills at the works of Monks, Hall & Company, Limited, Warrington. The present plant consists of two producers, each rated at 2000 horse-power; but one is kept in reserve. An analysis of the gas shows:—

CO <sub>2</sub> .	CO.	H.	CH <sub>4</sub> .	N.
12·6	14·6	25·6	3·6	43·6

Martin § discusses the properties of illuminating gas and power gas and the difference in the methods by which they are produced, giving the composition of various kinds of gas. The Mond system of gas production, with recovery of sulphate of ammonia, is described and illustrated.

**Gas-Power Plant.**—L. C. Gartzweiler || traces the evolution of modern gas-power plant, referring to the earliest records of the use of power generated by the ignition of an explosive mixture. A number of illustrations of recent gas-producing plant and engines are given.

G. Helps ¶ compares the cost of raising power with blue water-gas, Mond gas, ordinary coal-gas, coal and electricity.

The motors driven by poor gas are described by A. Abraham.\*\*

\* *Journal für Gasbeleuchtung*, vol. xlv. pp. 969-971.

† *Ibid.*, pp. 969-971.

‡ *Iron and Coal Trades Review*, vol. lxvii. pp. 1559-1563.

§ *Traction and Transmission*, 1903, pp. 152-161.

|| *Proceedings of the South African Association of Engineers*, vol. i. pp. 131-156.

¶ Paper read before the Midland Association of Gas Managers; *Iron and Coal Trades Review*, vol. lxviii. pp. 679-680.

\*\* *La Revue Technique*, 1904, January 10 and 25.

**Brown Coal Producer-Gas.**—A. von Ihering \* discusses the application of brown-coal fuel to the driving of internal combustion engines, giving a description of the producers employed to gasify the brown coal. A number of calculations relating to the calorific value and the composition of the gas is given.

Kegel † has worked out the comparative advantages of producer-gas engines and steam engines in brown-coal mining installations.

A producer plant worked with brown-coal briquettes has been installed at Hoyerswerda, Germany, for driving a gas engine and dynamo. ‡ Analysis of the briquettes shows:—

C.	H.	O+N.	S.	Ash.	H <sub>2</sub> O.	Total.
48.32	3.35	26.54	1.09	5.00	15.70	100.00

### VIII.—COAL MINING.

**Deep Boring.**—Cuvelette § describes in detail the deep borehole of the Béthune Mining Company. Recent borings have shown that there is a considerable extension of the North of France coalfield to the south. The deepest borehole in France is that put down by the Béthune Company. It has a depth of 4340 feet. ||

J. N. Justice ¶ describes some applications of the hydrofluoric acid etching method, and of the MacGeorge instrument for surveying inclined and other diamond boreholes in South Africa.

An illustrated description has been published \*\* of Meine's strata-meter, an instrument for ascertaining the direction and dip of beds encountered in deep boreholes.

An illustrated series of articles on the mechanical engineering of collieries, by T. C. Futers, is in course of publication. †† Much attention is devoted to deep boring.

**Underground Temperatures.**—The present knowledge on the subject of underground temperatures is summarised by J. D. Everett. ‡‡

\* *Braunkohle*, 1903, pp. 358-364.

† *Ibid.*, pp. 373-377.

‡ *Engineer*, vol. xcvi. p. 311.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1904, pp. 42-45.

|| *Ibid.*

¶ Paper read before the Institution of Mining and Metallurgy, April 1903; *Mines and Minerals*, vol. xxiv. pp. 161-165.

\*\* *Echo des Mines*, vol. xxxi. pp. 316-318.

†† *Colliery Guardian*, vol. lxxxvii. pp. 32, 70, 124, 177, 228, 297, 335, 387, 440.

‡‡ *Second Report of the Royal Commission on Coal Supplies*, vol. ii. p. 290.

Particulars are given by H. C. Jenkins\* of rock temperatures and the rate of increase with increased depths in Victoria.

R. Strachan† describes the construction of thermometers for ascertaining earth temperatures.

**Shaft Sinking.**—A series of articles by T. C. Futers‡ on the sinking of shafts has been published.

A. Marcette§ describes the deepening of a winding shaft at the Grande Bouillon colliery from 472 to 516 metres by working from below upwards. He also describes the walling stage at the Sacré Madame Pit, Dampremy.

L. Poussigue|| concludes his account of the method of sinking the deep shaft at Ronchamp in France, the first in which a depth of over 1000 metres has been exceeded in that country. Details of the pumping plant are given.

Some notes are communicated by Bouvier¶ upon the sinking of the Schneider shaft. The methods employed are described and illustrated.

E. Williams\*\* describes the sinking of the first steel-lined shaft in South Africa, on the property of the Free State Colliery Company, in the Orange River Colony.

Klose†† describes the sinking of the shaft of the Wintershall mine at Heringen with the aid of the Tomson processes.

It is stated that between July and September 1903 the sinking at Dover progressed at the rate of 15 inches daily with the Kind-Chaudron machine, of which illustrations are given.‡‡

R. R. Simpson§§ describes the method of sinking wells in the Punjab, through quicksand, by a brickwork cylinder and internal excavation.

\* *Report of the Ninth Meeting of the Australasian Association*, Hobart, pp. 309-318.

† *The Horological Journal*, vol. xlv. pp. 105-108.

‡ *Colliery Guardian*, vol. lxxxvii. pp. 494, 548, 600, 651, 704, 753, 807, 859, 912, 961, 1032, 1071.

§ *Annales des Mines de Belgique*, vol. viii. pp. 75-80, 87-91; *Colliery Guardian*, vol. lxxxvi. p. 1330.

|| *Bulletin de la Société de l'Industrie Minérale*, vol. ii. pp. 949-1058.

¶ *Comptes Rendus de la Société de l'Industrie Minérale*, 1903, pp. 213-221.

\*\* *Journal and Proceedings of the South African Association of Engineers*, vol. ii. pp. 3-5.

†† *Glückauf*, vol. xl. pp. 29-34.

‡‡ *Colliery Guardian*, vol. lxxxvi. pp. 662-663.

§§ *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 47-54.



J. H. Brace \* has collected descriptions of the various processes of sinking by the freezing process, and gives accounts of the different shafts which have been sunk in this way, and also of one tunnel. The paper is a synopsis of the literature of the subject; it appears to be very complete and to be of considerable value.

M. Unger † describes the arrangements to be adopted for sinking shafts to any depth through water-bearing strata by means of the freezing process.

W. V. N. Powelson ‡ describes the use of the freezing process for luting a leaky cofferdam.

The occurrence of quicksands in the Brûx-Dux brown-coal district is described by Von Banaston. §

W. E. Sanders || describes the framing of rectangular sets for timbering shafts, and shows how to lay out the half tenon and other joints used.

The question of iron tubbing with machined flanges is discussed, ¶ and illustrations are given of plant for sinking with a small trepan followed by a larger one.

Prein \*\* describes the methods taken to repair the Wilhelm shaft of the Frederick Wilhelm colliery at Dortmund, which collapsed in April 1902.

Some of the rectangular shafts at the collieries in the vicinity of Scranton have been lined with concrete strengthened by expanded metal. The method of lining is described and illustrated. †† The use of concrete for mining and other purposes is also dealt with in a series of articles. ‡‡

**Winding Appliances.**—A method of calculating the engine power required for a given load and lift is given, §§ taking into consideration the weight of all the moving parts, including the rope and drum. Curves are plotted showing the power required for acceleration during the wind.

\* *Proceedings of the American Society of Civil Engineers*, vol. xxx. pp. 20-91; *Iron and Coal Trades Review*, vol. lxxviii. pp. 757, 827, 896.

† *Berg- und Hüttenmännische Zeitung*, vol. lxii. pp. 601-603.

‡ *Engineering News*, vol. li.'p. 151.

§ *Bergbau*, October 22, 1903.

|| *Engineering and Mining Journal*, vol. lxxvii. pp. 396-398.

¶ *Colliery Guardian*, vol. lxxxvii. pp. 489-492.

\*\* *Glückauf*, vol. xl. pp. 263-265.

†† *Mines and Minerals*, vol. xxiv. p. 212.

‡‡ *Ibid.*, p. 257.

§§ *Engineer*, vol. xcvi. pp. 565-566.

The winding engines recently erected at the Dalton Main collieries, near Rotherham, have cylinders 48 inches by  $7\frac{1}{2}$  feet, with a 20-foot drum. An elevation and plan are given.\*

Illustrations are given † of the compound winding engine erected at the Sherwood colliery, near Mansfield, Nottinghamshire. The cylinders are 32 and 53 inches in diameter, with a stroke of 66 inches. It raises  $4\frac{1}{2}$  tons of coal per trip from a depth of 444 yards at the rate of 80 trips hourly. The boiler pressure is 150 lbs.

Illustrations are also given ‡ of the compound winding engine at the Bargoed pits of the Powell Duffryn Steam Coal Company. The high pressure cylinders are 32 inches in diameter, and the low pressure cylinders are 50 inches in diameter, the two sets being at right angles. The stroke is 6 feet, and the working pressure is 110 lbs. The coal raised weighs 5 tons 12 cwt., and is lifted from a depth of 625 yards at the rate of 300 to 350 tons hourly.

J. Divis§ publishes an account of the central condensation plant erected by the firm of Balcke & Co., of Bochum, at Przibram. Even so far back as 1846 the heavy fuel costs at Przibram led to efforts being directed to keep down as far as possible the fuel expenditure for the boiler plant, and the constant efforts which have since been made in this direction are briefly sketched.

C. C. Leach|| describes the use of superheated steam at the Seghill colliery.

Rodde¶ gives details of some trials made with the new winding engine at the St. Dominique colliery in France.

P. Malissard-Taza\*\* describes the mining machinery and material at the Düsseldorf Exhibition. The great advance made by Germany in the equipment of mines is emphasised, with special reference to winding plant.

F. Hird†† discusses the electric winding engine in its modern development. The heavy loss due to resistances in starting has received much attention and various substitutes have been adopted, such as variation of the voltage in different ways, and more especially

\* *Iron and Coal Trades Review*, vol. lxviii. p. 673.

† *Ibid.*, pp. 307-308.

‡ *Ibid.*, pp. 525-527.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 601-606, with three illustrations.

|| *Transactions of the Institution of Mining Engineers*, vol. xxiv. pp. 538-548.

¶ *Comptes Rendus de la Société de l'Industrie Minérale*, 1903, pp. 158-162.

\*\* *Bulletin de la Société de l'Industrie Minérale*, vol. ii. pp. 1059-1090.

†† *Transactions of the Institution of Mining Engineers*, vol. xxv. pp. 592-612.

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the use of storage batteries and of flywheels on the motor generator. This combination is embodied in the Siemens-Ilgner system. In two trials with a non-condensing engine for the generator and electric driving, the consumption of steam per effective horse-power hour on the useful load lifted was 114 lbs. and 70 lbs. This great reduction was owing to the fact that an expert was watching the winding engine. Under condensing conditions the consumption was 57 lbs. of steam. Some diagrams are appended of the amperes used in one winding-gear at Thiederhall, and they show that great economy may be effected by proper manipulation.

M. Georgi\* deals with the application of electricity to winding and other purposes.

G. M. Stevenson† describes the electric winding at Zollern II. colliery and compares it with a steam winding engine.

R. Herzfeld‡ discusses electric winding especially in connection with the Koepe system, and then describes the electric winding plant at the Grand Hornu colliery in Belgium, where a flat rope is used in a shaft 1093 yards in depth. It is stated that a plant is to be installed in Wales.

D. Selby-Bigge§ advocates electric winding. The electric winding engine at the Noel-Sart-Culpart collieries in Belgium is illustrated.||

In a report on a visit to mines in Westphalia, Austrian Silesia, and Prussian Silesia, J. von Lidl¶ describes and illustrates an electrically driven winding engine with cylindrical drums and another with Koepe pulley. The principal types of winding engines are discussed.

C. Bouché\*\* deals with electric winding engines.

Schulte†† gives the results of a determination of the steam consumption for the electric winding engine of the Preussen colliery.

The first winding plant worked by the aid of electricity yet erected in Austria was put into operation at the Tollinggraben collieries shortly before Christmas 1903. Details are given by J. von Lidl.‡‡

\* Paper read before the Manchester Geological and Mining Society; *Iron and Coal Trades Review*, vol. lxviii. pp. 769-760.

† *Proceedings of the South Wales Institute of Engineers*, vol. xxiii. pp. 462-476.

‡ *Engineering*, vol. lxxvii. pp. 214-215.

§ *Ibid.*, p. 297.

|| *Iron and Coal Trades Review*, vol. lxviii. pp. 1047-1050.

¶ *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. li. pp. 389-434.

\*\* *Bulletin de la Société des Ingenieurs de l'École des Mines du Hainaut*, vol. xii. pp. 465-510.

†† *Glückauf*, vol. xl. pp. 338-341.

‡‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 105.

H. Kuss \* describes various appliances for the prevention of over winding, including those of Sohm, Karlik, Schluter, Villiers, Lievin, Roemer, Baumann, Müller, and Reumaux.

Blosfeld's safety-brake for winding engines is also described.†

W. Dill ‡ discusses the use of safety-catches in the Dortmund district. Whilst in 1899 there were in use 65 of these appliances of 6 different patterns, the number at present in use is 124 and the number of patterns represented is 12. The most popular are the Roemer catch, of which there are 48, and the Baumann, of which there are 40.

G. Ryba § describes various forms of safety appliances for use in connection with winding methods of different kinds.

A number of safety arrangements intended to prevent accidents through overwinding are briefly mentioned, and one such arrangement described.||

T. E. Parrington ¶ describes the introduction of a balance-rope beneath the cages at the Hylton colliery.

Siede \*\* describes an automatic shaft-closing device that has been found to work well in practice.

Plans and sections are given †† of the arrangement at the pit bottom and the pit top at Bargoed colliery in the Rhymney Valley.

D. A. Louis ‡‡ deals with the coal deposits of Westphalia and with the plant in operation at the leading collieries, giving an illustration of the new pithead arrangement at Neumühl.

O. C. von Verbo §§ describes an endless-chain system of winding for use in collieries as designed for a shaft about 230 yards deep. In this connection, reference may be made to an account of an English colliery, thus equipped, which was given by T. A. O'Donahue.||||

E. H. Robertson ¶¶ deals with the limits and possibilities of deep

\* *Annales des Mines*, vol. iii. pp. 479-582; *Colliery Guardian*, vol. lxxxvi. pp. 1197-1236.

† *Iron and Coal Trades Review*, vol. lxxvii. pp. 1772-1773.

‡ *Glückauf*, vol. xxxix. pp. 1127-1130.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 547-550, 563-565, with one sheet of illustrations.

|| *Ibid.*, vol. lii. pp. 160-161, with four illustrations.

¶ *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 294-300.

\*\* *Glückauf*, vol. xxxix. pp. 1059-1062.

†† *Colliery Guardian*, vol. lxxxvi. p. 1288.

‡‡ *Page's Magazine*, vol. iv. pp. 35-42.

§§ *Colliery Guardian*, vol. lxxxvii. p. 547.

|||| *Journal of the Iron and Steel Institute*, 1899, No. II. p. 368.

¶¶ *Engineering Magazine*, vol. xxvi. pp. 546-560.

mining, more especially in view of temperature and winding. Various forms of winding machinery are illustrated and described.

G. H. Winstanley \* considers that the practical limit for ordinary systems of winding with ropes is a thousand yards.

**Winding Ropes.**—Luttermann † calculates the stresses produced in steel-wire winding ropes.

In the Dortmund mining districts the winding ropes in use are almost exclusively round and of crucible cast steel. At 126 collieries in this district in 1902 there were only 40 flat ropes which were made of cast steel, as compared with 408 round ropes of the same material. Nothing else has been used in this district for winding ropes since 1895. Eight ropes were replaced owing to fracture in 1902, one flat and seven round ropes having broken when in use. Various details as to the duration of the various kinds of ropes in operation are also given. The maximum work done by any one of the ropes that broke was 399,280 million kilogrammetres, as compared with a similar maximum of 791,110 million the year before. This rope had been in use for two years at the Ewald II. colliery near Recklinghausen. ‡

The round ropes made of charcoal iron wire, which were at one time common in the Breslau mining district, have now entirely gone out of use, round ropes of cast steel wire being here almost solely employed. In 1902, 157 ropes were replaced at 48 mines, but of these only one broke when in actual use, or 0·64 per cent., the lowest percentage for any year since these statistics have been compiled, beginning in 1882. Details are given as to the work done by the ropes replaced. §

**Underground Haulage.**—M. Buhle || deals with the Renold system of chain haulage.

H. Schmerber ¶ describes the safety appliances for inclined planes in use in Austrian collieries.

A. S. E. Ackermann \*\* describes the use of pneumatic and electric locomotives in and about collieries.

\* *Colliery Guardian*, vol. lxxvi. pp. 939-940.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. li. pp. 309-314.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 591-594.

§ *Ibid.*, pp. 624-626.

|| *Glückauf*, vol. xl. pp. 401-404.

¶ *Génie Civil*, vol. xlix. pp. 117-119.

\*\* *Transactions of the Institution of Mining Engineers*, vol. xxv. pp. 529-547.

G. Farmer\* discusses the comparatively slow adoption of electric haulage underground.

An illustrated account is given † of the polyphase hauling plant at the Bolsover colliery, Chesterfield.

Egger ‡ gives data relating to construction of some electric narrow-gauge mine locomotives. They are 9 feet long and 3 feet 7 inches wide, and weigh 16 tons, the rate of haulage being seven miles per hour up inclines of 1·8 in 100.

R. V. Norris§ gives some particulars and costs of working of the electric haulage plant at the Short Mountain colliery, Lykens Valley, Pennsylvania.

**Mine Supports.**—Illustrations are given || of fungi affecting mine timber, and a simple method of impregnating the wood is advocated.

Wex ¶ describes the impregnation of mine timber in the Dortmund collieries, showing the advantages of the use of coal tar products.

Middendorf's \*\* experience at the Nordstern colliery at Wattenscheid shows that iron props made of Mannesmann tubes have proved more economical than ordinary timbering. The cost of timber annually in one level was £72, whilst that of iron props was £41.

Particulars are given of the experience with iron supports at a colliery at Waldenburg in Upper Silesia. ††

**Electricity in Mines.**—The report of the Home Office Departmental Committee on Electricity in Mines has been issued. ‡‡ With regard to the pressure at which electricity should be used, the committee considers that a reasonable limit would be medium pressure, not in any case to exceed 650 volts. The chief points to be attended to in order to obviate risk are similar to those in using high explosives in mines, namely—(1) that the electric plant should always be considered a source of potential danger; (2) that the plant, in the first instance, should be of thoroughly good quality, and so designed as to insure immunity from danger by shock or fire, and

\* Paper read before the National Association of Colliery Managers; *Iron and Coal Trades Review*, vol. lxviii. pp. 603-604.

† *Colliery Guardian*, vol. lxxxvii. pp. 493-495.

‡ *Elektro-technische Zeitschrift*, 1903, pp. 825-828.

§ *Transactions of the American Institute of Mining Engineers*, February 1903.

|| *Iron and Coal Trades Review*, vol. lxviii. pp. 678-679.

¶ *Glückauf*, vol. xl. pp. 394-401.

\*\* *Ibid.*, pp. 333-338.

†† *Ibid.*, pp. 490-493.

‡‡ *Blue-Book* (Cd. 1916), London, 1904.

periodical tests should be made to see that this state of efficiency is being maintained; (3) that all electrical apparatus should be under the charge of competent persons; (4) that all electrical apparatus which may be used when there is a possibility of danger arising from the presence of gas should be so enclosed as to prevent such gas being fired by sparking of the apparatus; when any machine is working every precaution should be taken to detect the existence of danger, and on the presence of gas being noticed such machines should be immediately stopped.

In working electrically-driven coal-cutting machines where there is a possibility of igniting fire-damp, the committee point out the necessity for enclosing the entire motor in a flame-tight casing, and for frequent examination to see that the joints of the casing are in efficient condition. The tenor of the evidence given is in favour of requiring all shot firing of permitted explosives to be done by electricity, and, in electric lighting, of the cables being run in a continuous strong metal casing which should be well earthed.

Baum \* has published a detailed paper on the dangers from electricity in mining work.

A. C. Cormack † discusses the origin and prevention of failures in electric plant.

T. P. O. Yale ‡ deals with electric transmission by continuous current for mining purposes in North Wales.

A. Halleux § gives a note on the accidents due to the employment of electricity in mines and collieries in Prussia.

Illustrations are given || of the polyphase electric plant at the Staveley Coal and Iron Company's collieries. Another account ¶ deals with the three-phase plant at the Noel-Sart-Culpart collieries in Belgium.

E. H. Robertson \*\* deals with the development of power-driven machinery in the mine, and gives a large number of illustrations of pumping, winding, hauling, coal-cutting, and drilling machines.

The electric installations of the La Mure Mining Company are described by L. de Charentenay. ††

\* Glückauf, vol. xl. pp. 104, 125, 153, 185, 217, 249, 278.

† Transactions of the Institution of Mining Engineers, vol. xxv. pp. 548-579.

‡ Ibid., pp. 616-636.

§ Annales des Mines de Belgique, vol. viii. pp. 443-445.

|| Iron and Coal Trades Review, vol. lxvii. pp. 929-930.

¶ Ibid., vol. lxviii. pp. 1047-1050.

\*\* Engineering Magazine, vol. xxvi. pp. 925-949.

†† Comptes Rendus de la Société de l'Industrie Minière, 1903, pp. 198-200.

Schulte \* describes the electric power transmission plant at the Courl colliery, near Dortmund.

Richter † describes various electric central power plants installed in brown-coal mines, with special reference to the Brown-Boveri-Parson's system driven by steam turbines.

C. M. Warren ‡ describes the central generating electric plant of the coal-mining department of the Delaware, Lackawanna, and Western Railway Company at Scranton.

P. Sonntag § describes the new central electrical power plant at the Richard pit at Brüx. The rest of the plant generally is also described, the author considering it an excellent example as regards the brown-coal mines of North-West Bohemia. The plant was erected in 1900-1901.

**Compressed Air in Mines.**—Althans || discusses the expansive working of compressed air motors.

Terbeck ¶ gives the results of trials of an air-compressor with a Köster valve-gear.

J. Divis \*\* also gives illustrations of a new Riedler compressor erected at the St. Pancras colliery at Nürschan. Details are also given as to the results attained with the use of compressed air for power purposes at the Heinitz colliery at Saarbrücken.

**Explosives and Blasting.**—P. Hess †† discusses recent improvements in blasting and explosives, dealing specially with the danger of frozen dynamite, with aluminium explosives, and with fulminate of mercury.

A report by Brzezowski ‡‡ on the permitted explosives in the Ostrau-Karwin collieries has been published.

J. H. Karkeet §§ gives some notes on the handling of explosives and on their use.

\* *Glückauf*, vol. xl. pp. 389-394.

† *Braunkohle*, vol. ii. pp. 401-407.

‡ *Mines and Minerals*, vol. xxiv. pp. 197-201.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 647-651, 665-668, and 680-685, with a sheet of illustrations.

|| *Glückauf*, vol. xl. pp. 101-104.

¶ *Ibid.*, pp. 2-13.

\*\* *Ibid.*, pp. 81-84; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 81-85, with five illustrations.

†† *Glückauf*, vol. xl. pp. 57-59.

‡‡ *Die Bergwerks-Inspektion in Oesterreich*, Vienna, 1903.

§§ Paper read before the Lake Superior Mining Institute, August 1903; *Mines and Minerals*, vol. xxiv. pp. 137-139.



J. von. Lauer \* dates modern progress in safety shot-firing from the year 1886, when the companies working in the Ostrau-Karwin field offered a prize for some safe method of shot-firing in fiery collieries. The author traces the progress which has been made in this direction since then, electric methods being specially referred to.

A drilling apparatus specially designed for the safe removal of misfires has been designed to meet the official requirements by the Maschinen-Vertriebs Company at Gleiwitz in Upper Silesia. It is stated that by its aid a misfire may be rapidly drilled out, and this with complete safety.†

A. W. Warwick ‡ gives some further notes on the testing of detonators.

C. N. Hake § gives a note on the testing of the continuity of the powder column in safety-fuse by means of the X-rays.

Claessen || publishes the agreement arrived at by the Congress for Applied Chemistry, which was held in Berlin in 1903, in relation to the shapes of the lead cylinders to be used in testing explosives, and the way in which the test is to be carried out.

Descriptions are given of the experimental galleries for testing explosives at Gelsenkirchen and at Mons. ¶

**Coal-Cutting.**—A. Simon \*\* deals with coal-cutting machinery of the percussion type.

W. Walker †† describes the application of electrically-driven coal-cutting machinery, and gives a log of a run with a Hurd machine.

P. C. Greaves ‡‡ gives some results obtained with a Jeffrey heading machine.

L. J. Daft §§ offers some comments on different types of coal-cutting machinery, and on certain difficulties in handling the coal at the face after undercutting.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 587-589, 608-611.

† *Zeitschrift für Gewerbe-Hygiene*; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. p. 596.

‡ *Mines and Minerals*, vol. xxiv. pp. 302-303.

§ *Journal of the Society of Chemical Industry*, vol. xxii. pp. 1224-1225; *Colliery Guardian*, vol. lxxxvi. p. 1237.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 579-580, with two illustrations.

¶ *Colliery Guardian*, vol. lxxxvii. p. 125.

\*\* *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 322-330.

†† *Ibid.*, pp. 348-402.

‡‡ *Ibid.*, vol. xxvii. pp. 39-47.

§§ *Colliery Guardian*, vol. lxxxvii. pp. 236-237.

D. Burns\* describes the Anderson-Boyes coal-cutting machine, which is of the disc-cutter type, and driven electrically.

A. de Gennes† gives some notes upon the organisation of work in a colliery when adopting coal-cutting machinery.

J. Rosset‡ compares the advantages of the leading types of coal-cutting machines, and describes their method of working.

E. Guarini§ describes the electric coal-cutting machine of the Hurd-Mavor and Coulson type.

**Methods of Working.**—The second report of the Royal Commission on Coal Supplies has been issued.|| It contains much evidence on waste in working in the anthracite coalfield of South Wales.

Schreiber¶ records the experience obtained in packing excavations by the water-flush system in Silesian collieries. The cost of the new system at the Myslowitz colliery is 6d. per ton of coal. There is, however, a saving of 4d. per ton in wages, damming, and timber, so that the net cost is 2d. per ton of coal.

J. Mauerhofer\*\* describes the results that have been obtained with the water-flush system of filling old workings at the Trinity pit in Polnisch-Ostrau. The seams worked at this colliery are of a thickness ranging from 28 inches to 12 feet. Eight of these are mentioned, and the coal still remaining contains great quantities of coal. The colliery is right under the town of Polnisch-Ostrau. In the seams mentioned the pillars contain from a minimum of 166,450 tons to a maximum of 903,583 tons of coal, some 3,200,000 tons having been left altogether. These are now being mined, and the waste spaces are being filled up by a mixture of 35 per cent. marl, 25 per cent. stone from the dumps under about 3 inches in size, 30 per cent. sand and ashes and coke dust, and 10 per cent. of the waste separated from the coal in the washing plant. These materials are conveyed regularly in the same order to the mixing funnel, and from this through steel pipes into the old workings. The marl does not dry readily without the admixture of other substances, but the above mixture answers well. Care has, however, to be taken that the more porous portions

\* *Iron and Coal Trades Review*, vol. lxviii. pp. 179-180.

† *Comptes Rendus de la Société de l'Industrie Minérale*, 1903, pp. 31-40.

‡ *Génie Civil*, vol. xliii. pp. 182-186.

§ *Electrochemical Industry*, vol. ii. No. 10.

|| *Blue-Book* (Cd. 1991), London, 1904.

¶ *Glückauf*, vol. xl. pp. 59-62.

\*\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 1-5, with five illustrations.

of the small coke do not float away again with the waste water. To prevent this a twig dam is used. The steel tubes used are tested to withstand a pressure of eighty atmospheres. Other details are also given.

The water-flush system is also described by Seebohm,\* and by Bernhardt.†

Experiments have been made by Obst‡ with a view to ascertain what is the best material for the pipes to be used for the discharge of slime into collieries for the purpose of filling up the worked out parts. It has been contended by many that the greatest resistance to wear would be shown by pipes of hard steel, but this the author doubted in view of the opposite results shown in connection with the use of the sand-blast. The author therefore experimented with pipes made of various materials, those used in the first comparative test consisting of a cast-iron pipe (A), a weldless one of hard steel (B), and one of soft steel (C). Their chemical compositions were as follows:—

	Carbon.	Phosphorus.	Manganese.	Sulphur.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
A.	3·630	0·550	0·630	1·64
B.	0·345	0·020	0·804	...
C.	0·051	0·021	0·340	...

The metal B has a tensile strength of 39·2 tons per square inch, with an elongation of 15·6 per cent., and metal C a tensile strength of 24·6 tons per square inch and an elongation amounting to 23·8 per cent. Equal lengths of these various pipes were made to rotate continually in moistened sand contained in casks for a period of a hundred hours. The loss in weight was as follows:—

	Actual Loss.	Per Sq. Metre of Surface.
	Lbs.	Lbs.
Cast iron . . . . .	23·8	36·0
Hard steel . . . . .	9·0	13·5
Ingot metal . . . . .	8·4	12·1

\* *Jahrbuch für das Berg- und Huttenwesen im Königreiche Sachsen*, 1903, p. 3.

† *Zeitschrift Oberschles. Berg- und Hütten Verein*, vol. xlii. p. 446.

‡ *Stahl und Eisen*, vol. xxiv. pp. 238-242, with two illustrations.

It was evident, therefore, that the softer steel gave better results than either of the others. Other experiments gave similar results.

H. Niollet \* describes the method of working the thin seams of coal at the mines of Douchy. Some of these are folded in a most irregular manner, and a number of sections are given to show the means adopted for winning the coal.

A. Demeure † gives a description of the methods of working employed by the Société Civile des Charbonnages du Bois-du-Luc.

Some illustrated notes on mining in the Westphalian coalfield have been published by D. A. Louia ‡

W. R. Crane § describes coal mining in the south-western field of Indian territory, and gives illustrations of a number of pillar and stall workings and other details of collieries in the district.

Dorstewit || deals with the problem of mining brown coal in open-cast workings by mechanical means. The apparatus employed are described.

K. Balling ¶ deals with the system employed in mining the thick brown-coal seams of north-west Bohemia. Large pillars have had to be left, and the quantity of brown coal locked up in them is enormous. The author considers how these pillars may best be won. The average thickness of the seam is about 65 feet.

The methods of working employed in the brown coal mines of Bohemia are also described by K. Croy.\*\*

**Mine Drainage.**—H. Davey †† gives an interesting historical account of the Newcomen engine, with numerous photographs of existing engines of that type.

T. E. Stanton ‡‡ gives an account of experiments on the efficiency of centrifugal pumps. The four main questions studied are: (1) The relative efficiency of curved vanes and radial vanes at high speed;

\* *Bulletin de la Société de l'Industrie Minérale*, vol. ii. pp. 1091-1112, with nineteen illustrations.

† *Annuaire de l'Association des Ingenieurs Sortis de l'Ecole de Liège*, vol. xvi. pp. 479-496.

‡ *Page's Magazine*, vol. iii. pp. 483-486; vol. iv. pp. 195-202.

§ *Engineering and Mining Journal*, vol. lxxvi. pp. 577-581.

|| *Braunkohle*, vol. ii. pp. 341-348.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 617-623, 639-644, with one illustration.

\*\* *Braunkohle*, vol. ii. p. 431.

†† *Proceedings of the Institution of Mechanical Engineers*, 1903, pp. 665-704.

‡‡ *Ibid.*, pp. 715-766.

(2) the efficiency of the vortex chamber; (3) the efficiency of guide passages; (4) the possibility of high lifts by centrifugal pumps with a single wheel.

The theory of centrifugal pumps is described by E. G. Harris,\* with suggestions for designs.

E. S. Wight † describes the uses of boreholes for pumping purposes to convey the water direct to the surface.

Illustrations are given ‡ of a large compound Cornish cycle pumping engine, built for the Waihi mines, New Zealand, to raise 1500 gallons per minute from a depth of 1550 feet at seven strokes per minute, with the consumption of 730 horse-power. The steam cylinders are 60 and 110 inches in diameter, with strokes of 6 and 12 feet respectively. The plunger pumps are 23 inches in diameter, with a stroke of 12 feet.

Illustrations are given § of the pumping plant at the Miike collieries, Japan. It consists of four compound differential Davey pumps, and is designed to raise 13,000,000 gallons daily from a depth of 900 feet when running at six strokes per minute. The pumps have plungers 22 inches in diameter with a 12-foot stroke, and the steam cylinders are 45 and 90 inches in diameter, with the same stroke. The spear rods are 22 inches square.

Lehmann || has published a paper on the Riedler express pump. At the Engelsburg colliery the installation consists of a steam-driven dynamo of 1000 horse-power, making 105 revolutions per minute, and generating an alternating current of 2400 volts. This drives two motors coupled direct to the pumps, which when running at 150 revolutions are capable of raising 3·7 tons of water per minute from a depth of 600 yards. The capacity can be increased to 5 tons when running at 200 revolutions.

A. Fieber ¶ describes and illustrates the various forms of pumps which were shown at the exhibition held at Ausse in 1903.

Some illustrations are given \*\* of series turbines for working against a considerable head.

\* *Transactions of the American Society of Civil Engineers*, vol. li. pp. 166-252.

† *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 147-151.

‡ *Engineering*, vol. lxxvii. pp. 384, 385, 391.

§ *Ibid.*, pp. 151-153.

|| *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1391-1392.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 145-150, with eight illustrations.

\*\* *Engineering News*, vol. li. pp. 324-326.

The hydraulic pumps at the Attendorf colliery at Dalhausen are described by M. Unger.\*

Schulte† describes the electric pumps at the Neu-Iserlohn colliery. They raise 106 to 135 cubic feet of water per minute from a depth of 1300 feet.

Particulars are given‡ of the flooding of the Asdrubal colliery at Puertollano, caused by the river Ojailen breaking into the mine.

W. Thompson§ gives an account of the method adopted in building dams in the Nickel Plate mine at Rossland, to hold back water in an adjoining mine, where there was a head of 450 feet. They were built of brick arches and cement and proved equal to the work.

A. Faulds|| describes two forms of water-tight dams, one constructed of timber and the other of brick.

**The Ventilation of Collieries.**—J. A. Church¶ points out the advantages of supplying dry air, even if it is heated, in workings where the temperature is high. Under such conditions perspiration evaporates more freely, and a cooling effect is produced which is not felt by the men when the air is saturated.

A. Scheele\*\* describes the modes of ventilating brown-coal mines, and deals generally with the constituents of the air in these mines.

Stach†† gives an account of the results obtained at the anemometer testing-station at Bochum.

**Fire-damp Explosions.**—Details are given‡‡ of fire-damp explosions at the Königsborn colliery on February 13, 1902; at the Camphausen colliery on July 29, 1902; at the Anselm colliery on August 30, 1902; and at the Minister Achenbach colliery on December 13, 1902.

Earth tremors in the Dortmund coalfield are discussed by Dill.§§

W. H. Hepplewhite||| describes the Beard-Mackie attachment to

\* *Glaser's Annalen*, vol. liii. p. 173.

† *Glückauf*, vol. xl. pp. 53-57.

‡ *Gaceta Minera de Cataluña*, vol. iv. p. 109.

§ Paper read before the Canadian Mining Institute, March 1904; *Engineering and Mining Journal*, vol. lxxvii. p. 483.

|| *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 134-138.

¶ *Engineering and Mining Journal*, vol. lxxvii. pp. 431-432.

\*\* *Braunkohle*, vol. ii. pp. 443-446.

†† *Glückauf*, vol. xxxix. pp. 1149-1159.

‡‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. li. pp. 421-431.

§§ *Ibid.*, pp. 439-466.

||| *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 214-219.

safety-lamps for detecting fire-damp. A number of platinum wires are fixed above the flame, and they glow when the flame spires and reaches them.

**Coal-dust Explosions.**—J. Ashworth \* contends that absolutely dry air is the best to work and fire shots in ; but as that is not practicable, the places where shots are fired should be thoroughly wetted, and only sufficient moisture applied elsewhere to prevent dust from rising in clouds.

Shea † deals with coal-dust explosions.

**The Lighting of Collieries.**—The results have been published ‡ of an inquiry into the electric mine-lamps in use in the Ostrau-Karwin collieries. In consequence of W. Koehler's report on the subject, it was ordered that such lamps must fulfil the following conditions : (1) The average duration of light must exceed by at least an hour the duration of the shift ; (2) the casing of the electric current generator must be strong and water-tight ; (3) the incandescent lamp must be covered with an air-tight closing, thick protecting glass, protected by wire netting ; (4) means must be taken to prevent taking off the protecting glass ; (5) the poles of the battery must be so arranged as to obviate short circuiting underground ; and (6) the contact arrangement must be such that sparking can only happen without air access.

A description is given of the Mallet and Parent electric miner's lamp, with accumulator. The construction is very good, but the lamp presents no features of special novelty. §

The results of experiments with the new safety-lamp, brought out by the Bochumer Metallwaarenfabrik, are given. ||

**Underground Fires.**—For the extinction of mine fires the introduction of liquid carbonic acid into the workings where the fire has broken out is recommended. ¶

An illustrated description has been published \*\* of an ingenious

\* *Mines and Minerals*, vol. xxiv. pp. 97-100, 306.

† Paper read before the Derbyshire Colliery Under-Managers' Association ; *Iron and Coal Trades Review*, vol. lxxviii. p. 751.

‡ *Die Bergwerks-Inspektion in Oesterreich*, Vienna, 1903.

§ *Revue Noire*, 1903, pp. 337-338.

|| *Bergbau*, November 16, 1903.

¶ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1903, pp. 264-272.

\*\* *Glückauf*, vol. xl. pp. 134-135.

arrangement used at the Shamrock colliery at Wanne, Westphalia, for fighting mine fires. Compressed air is supplied to the men, working in smoke masks, through the sprinkling water-pipes.

**History of Coal-Mining.**—The origin of mining in the Ostrau-Karwin coalfield is described by K. Fadrus\* and A. Podrouzek.

B. Schulz-Briesen† deals with the improvements that have taken place in coal-mining since he first took charge of a colliery in the Essen mining district in 1863. Especial attention is devoted in this connection to the Rhenish Westphalian district, the opening up of which dates from the construction of the railway from Cologne to Minden in 1848.

K. Engel‡ discusses the ownership of mining property in the Ruhr coalfield.

**Mine Surveying.**—Schumacher§ discusses the determination of boundaries when the landmarks have suffered lateral dislocation from subsidence due to mining operations. Examples of the shifting of trigonometrical points in the Ruhr coalfield are given by Rothkegel,|| and Köndgen¶ gives examples of lateral dislocation caused by mining in the town of Essen. The observations of the declination of the magnetic needle made in German mining districts are discussed by J. B. Messerschmitt.\*\*

The modern methods of measuring base-lines in surveying are described by R. Bourgeois.††

Lenz‡‡ gives the results of the magnetic observations at Bochum during 1903. The greatest perturbation took place on October 31 with 140·9 minutes' amplitude. Other disturbances occurred on December 13 and 31, with 55 and 36·3 minutes amplitude respectively.

Discussing the evolution of mine-surveying instruments, Bennett H. Brough§§ gives a history of the invention of the micrometer eye-piece, and of the stadiametric principle.

\* *Hornike a hutnicke listy*, 1903. pp. 23-25.

† *Stahl und Eisen*, vol. xxiii. pp. 1019-1027, 1096-1102.

‡ *Glückauf*, vol. xl. pp. 404-405.

§ *Zeitschrift für Vermessungswesen*, vol. xxxii. pp. 97-119.

|| *Ibid.*, pp. 217-232.

¶ *Ibid.*, pp. 233-235.

\*\* *Ibid.*, pp. 681-686.

†† *Revue générale des Sciences*, vol. xv. pp. 376-386.

‡‡ *Glückauf*, vol. xl. p. 174.

§§ *Transactions of the American Institute of Mining Engineers*, vol. xxxiii. p. 1037.



G. R. Thompson \* discusses the transmission of errors in traverse surveying.

The composition of surveying parties and their methods of work in the anthracite mines of Pennsylvania is described. †

**Sanitation in Collieries.**—The literature concerning ankylostomiasis has recently received many further additions from J. S. Haldane ‡ and F. W. Gray.§

J. Barrowman || considers miners' phthisis.

A reprint of the official report on the debate on ankylostomiasis in the German Parliament, on January 12 and 13, has been published.¶ The debate arose out of a question by Auer and others as to what measures the Imperial Chancellor proposed to adopt to combat more effectively this rapidly spreading disease among the miners of Germany. The Home Secretary, in replying, pointed out that only two cases had occurred in Bavaria during the past year; in Saxony four cases had been reported, all being miners from Westphalia; and in Alsace-Lorraine seven cases had been reported, all introduced from Westphalia. Regulations had been adopted imposing compulsory medical examination of miners previously employed in Westphalia, and the rejection of all who failed to pass the medical examination. In the other states the disease was unknown. The report of the discussion that ensued occupies sixty-four pages. It was shown that in Westphalia the malady is diminishing, for in seven months 60 per cent. of the 12,157 sufferers were cured.

Ankylostomiasis has been found in the Sicilian sulphur mines.\*\*

The disease can be traced back at Selmeczbánya to the sixteenth century. It is mentioned in medical writings of 1740, and Hoffinger, who wrote in 1777–79, also describes it. Other interesting historical details relating to this disease among miners are also given. The first to make the true cause of this disease clear was probably Toth, who published an account of it in Hungarian in 1882.††

\* *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 75–87.

† *Engineering and Mining Journal*, vol. lxxvii. pp. 240–241.

‡ Parliamentary Paper (Cd. 1843); *Transactions of the Institution of Mining Engineers*, vol. xxv. pp. 643–669.

§ *Ibid.*, vol. xxvi. pp. 183–209.

|| *Ibid.*, vol. xxvii. pp. 21–32.

¶ *Glückauf*, January 23, 1904 Supplement, pp. 64; *Colliery Guardian*, vol. lxxvi. p. 242.

\*\* *Glückauf*, vol. xxxix. p. 1240; *Iron and Coal Trades Review*, vol. lxxviii. pp. 102–103.

†† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 130.

J. Mauerhofer \* describes the methods adopted for determining the pressure of gas existing in the oxygen bottles used in connection with the safety breathing apparatus.

A detailed report by Fillunger † on the rescue apparatus used in mines has been published.

## IX.—COAL WASHING AND SCREENING.

**Separating Slate from Coal.**—An illustrated description has appeared ‡ of several forms of mechanical pickers used for separating slate or bony coal from coal. Of these the first is the Allard screen, with stepped bars of angular section, which allow the flat pieces to drop through, leaving the coal. The earliest frictional devices were those of Thomas, in which the speed of the smoother coal down an inclined shaking surface is sufficient to pass it across a gap, through which the more slowly moving slate falls. This type is largely used for anthracite, and several modifications, such as those of Emery, Ziegler, Caryl and Snyder, and Langerfeld have been devised. Some of them are arranged so as to make three classes. Another type of machine, also depending on the relative frictional resistance, is the Pardee spiral picker, in which the greater velocity of the coal carries it over the edge of a spiral shoot.

C. F. Jackson § gives some notes on colliery surface plant.

**Coal Screening.**—L. Stockett || describes a bituminous coal-breaker, planned somewhat on the lines of machinery for preparing anthracite for the market, which was built in 1903 at Stockett, Cascade County, Montana. The coal treated is from a  $9\frac{1}{4}$ -foot seam containing  $7\frac{3}{4}$  feet of coal in the Kootenai group of the Lower Cretaceous series. It is dealt with in a series of crushers, belts, shaking screens, and spiral separators, and the general arrangement of the plant is shown by a number of sections and plans. About 2000 tons is treated daily, 200 tons of refuse, containing about 1 per cent. of coal, being separated. Costs are given.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lli. pp. 17-20, with thirty-six illustrations.

† *Die Bergwerks-Inspektion in Oesterreich*, Vienna, 1903.

‡ *Engineering and Mining Journal*, vol. lxxvii. pp. 317-319.

§ Paper read before the National Association of Colliery Managers, November 23, 1903; *Iron and Coal Trades Review*, vol. lxxvii. pp. 1637-1638.

|| *Transactions of the American Institute of Mining Engineers*, February 1904.

1904.—i.

G. H. Elmore\* compares the dressing of ores with the treatment of anthracite, and suggests that the methods used for ore might be applied to the fuel. On the picking belts all mixed material with over 2 per cent. of anthracite should be treated as middlings, and these with the middlings from other dressing processes should be treated by successive crushing, sizing, and separating operations in rolls and jigs.

**Washing Coal.**—Some notes have been published † on the effect of the pollution of streams by the discharge of acid water from coal waste heaps, which tend to show that a beneficial action is produced when there is much sewage contamination.

D. T. Blakey ‡ describes the Stewart washer as used for bituminous coal in Alabama. This washer is of the jig type.

J. V. Schaefer§ also describes the jiggling plant used for washing coal at Aldridge, Park County, Montana.

Illustrations and sections are given || of the coal screening and washing plant at the Dahlbusch, Germany.

A. Müller¶ gives a detailed description of the process of coal washing with various types of apparatus, and shows the principles involved in separating the coal from the shale. Some typical coal-washing plants at German collieries are described, among others the Baum and the Hinsemann coal washeries. Of other makers' apparatus the Elliot patent machine in England and the François Allard in Belgium are mentioned.

Particulars are given \*\* of a new coal-washing plant installed at Ronchamp. The Baum coal washer driven by electricity has been adopted.

F. Blanc †† has studied the nature of coals, and their classification by washing.

**Handling Coal.**—Sections are given ‡‡ of the Wrightson machine for loading coal at Percy Main, Northumberland.

\* Paper read before the Engineers' Club, Scranton; *Engineering and Mining Journal*, vol. lxxvi. pp. 928-929.

† *Engineering News*, vol. li. p. 175.

‡ *Mines and Minerals*, vol. xxiv. pp. 212-213.

§ *Ibid.*, pp. 228-229.

|| *Colliery Guardian*, vol. lxxxvii. pp. 72-74; *Iron and Coal Trades Review*, vol. lxxviii. pp. 101-103.

¶ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1748-1749.

\*\* *Echo des Mines*, vol. xxxi. No. 1571.

†† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1904, pp. 96-100.

‡‡ *Colliery Guardian*, vol. lxxxvi. p. 821.

Illustrations are given \* of a 25-ton coal hoist at Glasgow harbour for lifting railway waggons and discharging them into vessels.

An abstract of a committee report prepared for the annual convention of the American Railway Engineering and Maintenance of Way Association at Chicago has been published.† Piers where coal is handled by gravity are by far the most common. There are two general designs for these piers: (A) Piers having berths or water on one side only, such as a pier alongside of a canal. (B) Piers having berths or water on both sides, such as piers running out into the water. These two designs are further divided into: (1) Piers having locomotive inclines, or where the cars are placed on the upper level by a locomotive; (2) piers having inclines up which cars are hauled to the upper level by means of a cable and stationary engine; (3) piers where cars are run on to the pier at the upper level by gravity.

Some particulars have appeared ‡ of the work done at Boston, United States, with the Hunt unloading plant for bituminous coal, at the rate of 320 tons raised 90 feet from one hatch.

J. Pohligh§ describes the newer developments of the Hunt elevating and transporting plant for discharging bulk cargoes. He gives an account of a large plant for handling coal at Savona, and a smaller one carried out as a travelling cantilever crane for the Sabang Company in the Dutch East Indies.

J. Prudhomme|| describes the new coal-loading installation at the mines of Dourges.

**Firing with Coal Dust.**—C. O. Bartlett¶ discusses the principles involved in coal-dust firing. Uniformity in the degree of moisture and in the size of the particles is essential, and the air for combustion must be carefully controlled. The method of preparing the coal by crushing is described, and results are given of some experiments in firing. He also deals \*\* with the drying of minerals by direct heat, by heated air, and by steam. Clayey matters, peat and coal receive especial attention, particularly powdered coal for coal-dust firing. Coal dries best when the ash is siliceous and a good draught of air is maintained through it.

\* *Engineer*, vol. xcvi. pp. 499, 503, with plate.

† *Iron and Coal Trades Review*, vol. lxxviii. pp. 975, 1054.

‡ *Iron Age*, October 1, 1903, p. 15.

§ *Jahrbuch der schiffbautechnischen Gesellschaft*, vol. v. pp. 524-537.

|| *Bulletin de la Société de l'Industrie Minérale*, vol. ii. pp. 1125-1133.

¶ *Journal of the Association of Engineering Societies*, 1903, pp. 44-48.

\*\* *Transactions of the American Mining Congress*, Deadwood, 1903.

**Briquettes.**—R. Schorr\* deals at some length with the manufacture of fuel briquettes. After some historical notes, the present condition of the fuel briquette industry in America is considered, several plants being now at work. The form of the briquettes and their manufacture and use in Europe are considered. For burning on plain grates, the air-spaces should be  $\frac{1}{8}$  to  $\frac{5}{32}$  inch wide, the ratio of heating surface to grate 30 or 40 to 1, and the draught  $\frac{1}{8}$  to 1 inch of water. The coal used in the manufacture should be in grains ranging from  $\frac{3}{32}$  to  $\frac{1}{4}$  inch in size, and the ash should not exceed 6 per cent. For the binding agent, tar or pitch is preferred, but starch, seaweed, and molasses have been used. Among the inorganic materials used as binders, water, glass, and magnesia cement are of most importance. Thorough mixing is necessary to economise the binding agent, and heat should be employed. With superheated steam, about 10 lbs. of fuel is required per ton of briquettes. The temperature should be about 200° to 230° F. for hard pitch, and 100° F. for softer binding agents. Presses should apply the pressure on both sides of the block in order to obtain a more uniform product and to economise in power. In a block 5 by 12 inches pressed on one side only, the density ranged from 1.25 through 1 to 1.15 on the fixed side. The various types of presses are briefly considered and some details are given of costs.

E. Lozé† gives further notes on the briquette industry in France, classifying the plant used and mentioning the conditions required for the products.

The manufacture of briquettes of small size is discussed by H. Steger‡. The use of such briquettes, he observes, has become widely extended in recent years. They can be made with any machinery that will make bricks. Stamping appliances are therefore employed, by which loose material in moulds is compressed into shapes. To do this as evenly as possible the briquette should be compressed from above and below at the same time. In one form the moulds are attached to a revolving table, one mould after the other being brought under the press. Other forms are also mentioned. Tangential presses are very numerous. These are arranged much like a pair of rolls with corresponding parts of the press on the upper and lower halves. By far the most commonly employed form is that in which a stamp

\* *Transactions of the American Institute of Mining Engineers*, February 1904.

† *Engineering and Mining Journal*, vol. lxxvi. pp. 431–432; compare *Journal of the Iron and Steel Institute*, 1903, No. II. p. 618.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1313–1317, 1393–1401, with eighty illustrations.

moving backwards and forwards compresses material in a pressure cylinder. On the back stroke of the stamp-head a fresh and definite quantity of material is charged into the cylinder. When the stamp moves forward again the fresh material is moulded up against the last made briquette, which is pushed somewhat forward. Finally the compression of the fresh material in front of the cylinder is accompanied by the expulsion of one of the previously formed briquettes at the back. There is, of course, considerable friction to be overcome between the sides of the cylinder and the material under compression, but this is all the work the moving stamp has to perform. So far briquettes have been chiefly used for house fuel, and for this purpose they have been made of large size. For industrial purposes these are not satisfactory, the large pieces being difficult to charge by the shovel, and their smooth surface preventing their ready ignition. Again, their definite shapes cause them to pack too closely on the fire. They have to be broken up on the bars by the fireman, and this renders the work more difficult, much smalls also resulting and considerable loss. It was therefore found desirable to use other presses specially intended for the production of small-sized briquettes suitable for such industrial use. They proved commercially a failure, however, as ordinary house briquettes could not be also made. The further elaboration of the efforts to achieve success in this direction are detailed by the author.

An illustrated article on the agglomeration of coal has appeared.\* The various methods of compression are described, special attention being devoted to the system of double compression. The three types of machines are (1) presses treating the coal in open moulds (Evrard press, Bourriez press); (2) simple presses with a piston acting on a closed mould (Mazeline, Middleton, Dupuy, Bietrix presses); and (3) double press with two pistons acting in opposite directions (Middleton, Couffinhal, and Veillon presses). The details given tend to show that the best results are obtained with the Veillon press.

Auguste Lemoine † discusses the agglomeration of brown coal. He is of opinion that in many cases an unnecessarily large proportion of adhesive material is used.

\* *Revista Minera*, vol. lv. pp. 145-151.

† *Echo des Mines*, vol. xxxi. pp. 156-157.

# PRODUCTION OF PIG IRON.

## CONTENTS.

I. Blast-Furnace Practice . . .	PAGE 562	III. Blast-Furnace Slags . . .	PAGE 565
II. Chemical Composition of Pig Iron . . .	580	IV. Foundry Practice . . .	586

### I.—BLAST-FURNACE PRACTICE.

**Construction of Modern Blast-Furnaces.**—E. Lamoureux\* discusses the various points that have to be borne in mind in the construction of modern blast-furnaces, and the plant used in connection with them is also referred to.

Some illustrations of the modern blast-furnace are given by A. Humboldt Sexton.†

The first part of the third volume of the second edition of H. Wedding's exhaustive work on the metallurgy of iron‡ has been published. It is devoted to blast-furnace practice, and covers 348 pages with 231 illustrations.

**Stock Distribution in the Blast-Furnace.**—D. Baker§ discusses stock distribution and its relation to the life of the blast-furnace, and points out that modern charging apparatus is responsible for a much greater breakage of coke than resulted from the old hand-barrow system of charging. An example of the difficulties that were encountered from the excessive pulverisation of the coke is given.

\* *Stahl und Eisen*, vol. xxiv. pp. 387-392.

† *Engineering Review*, vol. x. pp. 7-15.

‡ *Ausführliches Handbuch der Eisenhüttenkunde*, Brunswick, 1904.

§ *Transactions of the American Institute of Mining Engineers*, February 1904.

They were partly overcome by rendering the slag more fluid by the addition of silica and by screening the coke before charging. It was also found that the charging machine did not work uniformly, the charge being piled on one side of the bell. To obviate some of these difficulties, an elliptical form of hopper, of which illustrations are given, was fitted to the furnace. Subsequent modifications had to be introduced, with the final result that a very considerable improvement was effected, and local burning on one side of the furnace, with constant local destruction of the lining, was obviated.

**Flue Dirt and Top Pressure in Blast-Furnaces.**—In the discussion of a paper by F. L. Grammer\* on this subject, F. Firmstone† points out that the top pressure is considerably affected by variations in the temperature of the gas, which affects the weight of the gas in the down-comer.

**Hearth Area and Tuyeres.**—F. L. Grammer‡ discusses the hearth area and number of tuyeres in blast-furnace practice. The use of fine ores has emphasised the fact that intimacy of contact between gases, coke, and ore are more important than time of exposure, but the advantages of increasing the number of tuyeres is not always permanent. No one, within the last few years, has had the temerity to use more than one row of tuyeres, and fancy forms of tuyeres have not come into use, although they are suitable on rare occasions. In no hearth can much relief of pressure be obtained by increasing the number of tuyeres above eight. With sixteen tuyeres, in fact, the pressure is increased, owing to the air friction in the smaller diameters. On the other hand, with larger numbers, tuyeres are less likely to be lost or burnt out, and the settling of the charge is more even. Extra tuyeres are useful when the furnace is working irregularly, and they can be plugged when they are not required. With Lake Superior ores, excellent results are obtained in an 85-foot furnace, having an 11- or 12-foot hearth and eight tuyeres. From this it is deduced that a 14-foot hearth would require 12 or 14 tuyeres, and the pressure would be increased from 10 to 14½ lbs. per square inch. Owing to the different height of the coke subjected to the blast before and after tapping, the combustion zone extends

\* *Journal of the Iron and Steel Institute*, 1903, No. II. p. 624.

† *Transactions of the American Institute of Mining Engineers*, October 1903.

‡ *Ibid.*



upwards to a greater height, and the heat is more intense in narrow hearths, and to some extent this explains the increase in silicon contents compared with that of iron made in a wider furnace. Lower furnaces would thus benefit more than higher ones by increasing the number of tuyeres, and large hearths and an increased number of tuyeres tend to lower the silicon. The size of the hearth largely depends on the nature or porous character of the coke, and also on the volume and temperature of the blast; but the selection under fresh conditions can only be made empirically. Some of these points are briefly discussed. In less than thirty years the ratio of hearth to bosh area has increased from  $\frac{1}{16}$  to  $\frac{9}{16}$ , and the furnace capacity, in cubic feet per ton of iron produced, has decreased from 380 to 20 or 30 feet, the latter figures applying to furnaces melting Mesabi ores. In modern American practice, the crucible capacity is 3 to 3.5 cubic feet per ton of iron produced in 24 hours.

**Failure of a Blast-Furnace Lining.**—F. Firmstone\* describes the failure of a blast-furnace lining in a furnace 75 by 18 feet, which was blown in during May 1902, and used to smelt magnetic ore with coke. The upper part of the lining had totally disappeared before a year was out. The brick used is considered by the author to be of good quality, and analyses are given. The result is ascribed to the deposition of carbon.

**Charcoal Blast-Furnaces.**—W. G. Mather† gives some historical notes on the charcoal iron industry of the upper peninsula of Michigan, and deals with the amount of forest land utilised for the production of charcoal for modern plants.

The charcoal blast-furnace at Newberry, Michigan, is 50 feet in height and  $10\frac{1}{2}$  feet in diameter at the boshes. Its record is 87 tons of iron in one day.‡

A. Byström§ states that the Widlitz blast-furnace plant is situated in the Olonetz Government, Russia. It comprises two charcoal blast-furnaces, one with a closed top the other with an open throat. Their dimensions are as follows:—

\* *Transactions of the American Institute of Mining Engineers*, October 1903.

† Paper read before the Lake Superior Mining Institute; *Engineering and Mining Journal*, vol. lxxvi. p. 432.

‡ *Iron Age*, March 17, 1904, p. 3.

§ *Stahl und Eisen*, xxiii. vol. p. 1223.

	No. I.	No. II.
	ft. in.	ft. in.
Height . . . . .	57 6	58 3
Diameter at tuyeres . . . . .	5 6	6 0
Diameter at boshes . . . . .	13 0	11 0
Diameter at throat . . . . .	9 0	8 0
Height of tuyeres above bottom . . . . .	2 6	2 6
Number of tuyeres . . . . .	5	5

The blast is heated to about 400° C. About 1 ton of charcoal is consumed per ton of pig iron made, and the output amounts to about 40 tons a day. For a time No. I. furnace worked with 80 per cent. of a concentrate containing 60 per cent. iron and 4 per cent.  $\text{TiO}_2$ , and the other furnace with 100 per cent. of this, and in neither case had the concentrates been converted into briquettes. No difficulties were experienced. These concentrates are obtained by a wet magnetic treatment of a titaniferous magnetite.

Some photographic illustrations have been published \* of the manufacture of charcoal iron in Mexico in the State of Jalisco. Figures are given showing that the cost of production is less than in Europe or in the United States. The two mines of the company are known as the Ta Cotes and La Mora. The former is an open draft of black magnetite, of which some 5,000,000 tons are in sight. The La Mora deposit consists of red hæmatite in limestone. Analyses of the ores yielded the following results :—

	Ta Cotes.	La Mora.
Iron . . . . .	68·20	64·60
Manganese . . . . .	trace	0·06
Phosphorus . . . . .	0·48	0·05
Sulphur . . . . .	0·18	0·30
Silica . . . . .	2·72	5·41
Alumina . . . . .	0·09	0·21
Lime . . . . .	trace	0·28

The ore is taken from the mines at a cost of 1s. 1½d. a ton, delivered in sacks, and is then transported on the backs of mules to the works at a contract price of 9s. per ton.

### The Stapf Continuous Blast-Furnace.—A. Sattmann † dis-

\* *Modern Mexico*, vol. xvi. pp. 24–28.

† *Stahl und Eisen*, vol. xxiii. pp. 1224–1227, with two illustrations; vol. xxiv. pp. 299–300, with nine illustrations.

cusses the Stapf blast-furnace. This is arranged for the continuous discharge of the pig iron and slag produced. The iron flows away from a kind of syphon discharge, the slag flowing off at a higher level from a separate opening. The idea of allowing the iron to flow away continuously is by no means new, the author points out, and he draws attention to a design of his own of this kind which he fully described and illustrated.\*

Every blast-furnace manager knows that the pig iron resulting even from the same tap is never of identically the same composition throughout. This is due to the iron that has been longer in the hearth taking up more carbon from the coke with which it had come in contact than that which had only reached the hearth a short time before the furnace was tapped. The result would therefore be, in a furnace from which the iron was continually running away, that the metal would be hotter but lower in carbon than metal from furnaces tapped at intervals, as is now customary. Such an iron would, however, be better for the open-hearth steel process.

The author describes a method of his own for continuous discharge and separation of the slag from the metal, and for this he claims numerous advantages. Amongst these is that to bring about the change from an intermittent to a continuous discharge would cost comparatively little, and if it was desired at any time to revert to the existing method of tapping, the change would only take a few hours to effect.

D. P. Shuler† points out that the forehearth, or slag and metal continuous separating and tapping device described by Sattmann, is very similar to that which has been used for many years in copper smelting furnaces for separating matte and slag.

**Blast-Furnace Fuel.**—O. Simmersbach‡ draws attention to the very greatly reduced consumption of iron in Germany. In 1902 this was actually equivalent to only 50 per cent. of the total production of pig iron in the German Customs Union. This has had for its result the necessity for German works finding a market for the products elsewhere, and this in its turn has necessitated an endeavour to reach a minimum first cost. Not the least important point connected with this is the character of the fuel used. The chief requirement in coke is strength, hard coke being less injured by transport than

\* *Stahl und Eisen*, vol. xix. pp. 956-966. † *Iron Age*, December 24, 1903, p. 33.

‡ *Stahl und Eisen*, vol. xxiv. pp. 157-163.

soft coke, while the quantity of dust delivered with the coke ought never to exceed 6 per cent. Every per cent. of coke lost in this way represents, with three 100-ton blast-furnaces, £1600 a year. This is, however, not the main point for consideration, which is, that the coke must not crumble in the blast-furnace when in contact with the charge. The softer the coke, the more smalls form in the furnace, and the less freely can the gases penetrate the charge. In modern furnaces the higher blast pressure and the more rapid descent of the charges further increase the loss of coke in this way, and incidentally, through this increase, the cost of the process. The actual height of the furnace is not of the importance that is often attributed to it, as the mere weight of the charge, as the author shows, is insufficient to crush the coke. Indeed, he gives figures showing that in the case of a 98-foot furnace the mere weight of the charge on the square foot does not reach more than about the three-hundredth part of the pressure required to crush even the poorest sample of coke. Soft coke in the blast-furnace has the further disadvantage of being much more readily oxidised in the blast-furnace by the carbon dioxide present than hard coke, with the result that more carbon monoxide passes into the waste gases. Other disadvantages connected with this lie in the reduction of the temperature at the point where this occurs, and in the diminished quantity of coke that reaches the tuyere level. The relative quantity of the ash present is also of importance from this point of view, as it has to be fluxed away.

The porosity of the coke is next considered, and then attention is given to the general analysis of the coke and ash, the influence of the sulphur present in it, the moisture also present, &c. As a result of his considerations the author gives the following formula by which the furnace value of the ton of coke may be calculated :—

$$x = a + \left( \frac{b \cdot 18.92 + c \cdot 6.92 + d \cdot 3.95 + e \cdot \frac{a}{100}}{100} \right).$$

In this formula  $a$  is the price of a ton of a standard coke containing 9 per cent. ash, 4 per cent. moisture, 1 \* per cent. sulphur, and 6 per cent. dust.;  $b = +$  the difference in per cent. between the actual contents of ash and the normal above mentioned;  $c = +$  the difference per cent. between the normal percentage of moisture, 4, and that actually present;  $d = +$  the difference in tenths per cent. between the normal sulphur contents of 0.1 \* per cent. and that actually found

\* Both as in original; apparently 1 per cent. is correct.

by analysis; and  $e = +$  the percentage difference between the normal dust contents of 6 per cent. and that actually present.

**Pump for Ironworks.**—Illustrations are given \* of a large pumping engine built for the North-Eastern Steel Company, to deliver 180,000 gallons hourly for tuyeres and surface condensers.

**Blowing Engines.**—Illustrations are given † of a 750 horse-power blowing engine, driven by blast-furnace gas engines, and constructed by Richardsons, Westgarth & Co. The Southwark valve gear is applied to the air cylinder.

Illustrations are given ‡ of a new design of blowing engine, of which three have been erected by the Westinghouse Company at Toledo and three at the South Chicago Works. The arrangement is the long crosshead type with three engines in line, the centre one being used as the low pressure stage in conjunction with either of the other two. The steam cylinders are 50 and 96 inches in diameter, and all the air cylinders are 96 inches; the common stroke is 66 inches.

**Motive-Power from Blast-Furnace Gas.**—K. Gruber§ discusses the use of blast-furnace gas in a modern ironworks, considering that it might be made adequate for all motive-power necessary at the works. The first engines erected for the use of this gas served only for the generation of electricity, but subsequently these gas engines were coupled direct to the blast-furnace blowing engines, and of late the gas engine worked by waste gas from the blast-furnaces has entered into sharp competition with the steam-driven engine. Finishing mills with electric power, in which the generating motor is driven by such a waste-gas engine, are already in use, and of late, in rolling mills adjacent to the blast-furnace plant, the blast-furnace gas engine has at times been coupled directly to the mills instead of the above indirect method. The author thinks that the time may not be far distant when these gas engines will entirely replace steam engines in ironworks, and he considers such a possible case in detail, assuming the existence of a plant comprising four 300-ton blast-furnaces, a basic

\* *Engineer*, vol. xcvi. pp. 180-181.

† *Engineering*, vol. lxxvii. p. 326, with plate.

‡ *Ibid.*, vol. lxxvi. pp. 797-799, 802, with plate; *Iron Age*, December 3, 1903, pp. 4-9.

§ *Stahl und Eisen*, vol. xxiv. pp. 9-14.

Bessemer plant with four 18-ton converters, an open-hearth plant with two 25-ton basic-lined open-hearths, and the necessary rolling mills of various kinds. Dealing in the first place with the question of the available excess of blast-furnace gas, the author bases his calculations on a consumption of a ton of coke per ton of pig iron made. In such a case, for each ton of pig iron there will be 4500 cubic metres of gas. The stoves would require one-half of this, and there would consequently be left 2250 cubic metres of gas for all other purposes. With a better form of construction of the stoves, and a more sensible way of heating them, a saving of gas for this purpose could doubtless be effected. One cubic metre of gas has an average calorific value that varies between 700 and 900 calories, and this may be taken in the mean as 800 calories. Three cubic metres may therefore be calculated as adequate for the horse-power hour, and there would thus be available for each ton of pig iron made gas of the value of 31·2 horse-power hours. The author estimates that of this there would be required for the blast-furnace blowing engine, pumps, hoists, &c., 7·5 horse-power hours, leaving a balance of 23·7 for other purposes. When minette ore is being smelted, there are usually employed 1·1 ton of coke for each ton of pig iron made, corresponding to the production of 5000 cubic metres of gas for each ton of pig iron made. The author next proceeds to consider the freeing of the blast-furnace gas from dust, and then passes to its use in the gas engine, the varying types of these and the power consumed by the various plants employed at the works, each of these latter being dealt with.

A translation of Gruber's paper has appeared.\*

P. Eyermann † gives a calculation to show the possible disposal of gas from blast-furnaces making 500 tons daily. Part of the gas is to be used for making steel in the open-hearth.

The memoirs on the use of blast-furnace gas communicated to the Iron and Steel Institute are summarised in a memorandum prepared for the Royal Commission on Coal Supplies by Bennett H. Brough.‡ Evidence on this subject was also given by B. H. Thwaite.§

The most suitable form of construction for a boiler when fired by blast-furnace waste gases is considered by Perelli.||

\* *Iron Age*, March 17, 1904, pp. 10-11.

† *Iron Trade Review*, October 22, 1903, pp. 47-52.

‡ *Second Report*, 1904, vol. ii. p. 375.

§ *Ibid.*, p. 242.

|| *Mittheilungen aus der Praxis des Dampfkessel-Betriebes*, 1903, pp. 706-708.

Illustrations are given \* of a 700 horse-power double-acting gas engine on the Körting system, built by Mather & Platt of Manchester.

A description has appeared † of the 1000 horse-power gas engine of the Oechelhäuser system lately installed at the Ilsede Works, near Hanover. The motive-power is derived from blast-furnace gas.

K. Machacek ‡ describes the 600 horse-power twin gas engine of the Cockerill type recently installed at the Kladno ironworks. The motive-power is supplied by blast-furnace gas, and it is applied to the driving of a dynamo generating a polyphase current of 550 volts. The method of cleaning the gases by fans has been adopted, two fans being arranged tandem fashion.

A series of statistical data are given by E. Neuberg § which deal with the rise and progress of the gas engine and cover the years 1881-1901. The different types of gas engine are also dealt with separately. It is shown that their average size in 1901 was in about the ratio of 2.5 to 1 as compared with those in use in 1881.

E. Theisen || describes the Theisen centrifugal method for freeing blast-furnace gas from dust, the gas and water flowing spirally in opposite directions. The hotter the gas the better does the apparatus work. The author also describes a modified method in which the washing and cooling processes are kept separate. A number of results are given showing the success attained with the centrifugal apparatus at Hochdahl, Schalke, Hörde, and Rombach. In these the cubic metre of gas before it entered the washer contained from 2 to 6 grammes of dust and from 18 to 42 grammes of moisture. After passing the washer the gas only contained from 0.004 to 0.04 gramme of dust per cubic metre and from 3 to 7 grammes of water, with the exception of the Rombach works, where the moisture was only reduced from 42 grammes to 32 grammes. Three sets of results relate to warm untreated gas, and three to cooled gas that had been subjected to a preliminary cleansing. Details of working costs are given. It is stated to amount to less than a third of that of the fan method, or about 0.146 shilling per 1000 cubic metres of gas.

\* *Engineering*, vol. lxxvi. pp. 596-598, with plate.

† *Electrical World*, 1903, pp. 877-878.

‡ *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereines*, vol. lv. pp. 618-623.

§ *Stahl und Eisen*, vol. xxiv. pp. 198-200.

|| *Ibid.*, pp. 285-290, with one illustration.

An illustration is given \* of Thwaite's apparatus for cleaning blast-furnace gas.

**English Blast-Furnace Practice.**—In a note † on the metallurgical progress of last year, the increased use of 300-ton blast-furnaces on American lines is noted in this country, with modifications in the hoisting arrangements to suit varying classes of ore and friable coke. Blowing engines in England and on the Continent are mentioned, and also the practice of coking near the furnace. At Donawitz and Eisenerz, however, coke is brought from a long distance and stored while the iron production has been concentrated in three furnaces of 250 to 400 tons capacity.

**Canadian Blast-Furnaces.**—The new plant of the Londonderry Iron Works, Nova Scotia, includes two blast-furnaces, of which one is 75 feet in height with 17-foot boshes, a 10-foot hearth, and a diameter of 11 feet at the stock line. All the ores are delivered into bins from the railway waggons, and are drawn thence to a crusher plant consisting of one Gates machine and one Blake crusher capable of dealing with 400 tons daily.‡

**The Elba Blast-Furnaces.**—An illustrated description has appeared § of the Elba blast-furnace plant at Porto Ferrario. Coke is made in 104 Fabry-Linard ovens. There are two blast-furnaces; each is 77 feet in height, with 20-foot boshes, 10-foot hearths, and 14-foot mouth, and has six 5½ inch tuyeres. Gas is passed through a Theisen purifier driven by a 5 horse-power motor. Vertical hoists, capable of lifting 1300 tons 92 feet in twenty-four hours, are used, and are worked by electromotors. The electric plant and the unloading plant are also described.

An illustrated description is given || of the Elba blast-furnaces, which have been in operation since August 1902.

E. Boucher ¶ describes the wire ropeway at the Elba ironworks.

**Spanish Blast-Furnace.**—Details are given \*\* as to the No. 4

\* *Iron Age*, December 3, 1903, p. 24.

† *Engineer*, vol. xcvii. p. 22.

‡ *Iron and Coal Trades Review*, vol. lxxvii. pp. 930-931.

§ *Ibid.*, pp. 1701-1702.

|| *Boletín Minero*, vol. vii. pp. 115-119.

¶ *Genie Civil*, vol. xlv. pp. 149-151.

\*\* *Revista Minera*, vol. lv. pp. 34.



blast-furnace of the Viscaya Ironworks. Blown in at the beginning of 1902, this furnace has since worked continuously down to November 30, 1903. The blast is heated in five Cowper stoves, and the furnace, with an internal capacity of 13,420 cubic feet, was built for a daily output of 150 tons. Three of the stoves are of relatively small size, and are to be increased to a height of 91 feet. At present these three are under 60 feet in height. The other two are about one-third higher.

**Swedish Blast-Furnaces.**—Dealing with the recent increased outputs of Swedish blast-furnaces, H. E. Tholander \* observes that it might be thought that it was merely dependent on the quantity of blast employed. This is not so, however, for a blast-furnace will not take any given quantity of blast without bears or other accretions forming in the furnace, which increase the consumption of charcoal and cause the furnace to work badly. To keep down as far as possible the consumption of fuel the blast-furnaces have to be kept as wide as possible, and the author deals with the changes that have taken place in the internal dimensions of the furnaces employed. He prefers to retain as the angle of the boshes  $78^{\circ}$ , or, better still,  $80.5^{\circ}$ . Some of the furnaces were also increased in height. At first the author increased the number of tuyeres to four only, and this proved adequate if the weekly output did not exceed 140 tons, and if the charcoal was of the customary character. In 1897 a new furnace was blown-in near Köping, which was intended to have a weekly output of 200 tons. The charcoal available was poor, and four tuyeres proved inadequate, the temperature not being evenly enough distributed at the tuyere level. In May 1900 the number of the tuyeres was increased to eight, with the result that the working of the furnace improved to such an extent that the output per week rose to 250 tons, and even more. In view of this the author increased the number of tuyeres at other furnaces which he names from four to six. With regard to the blast-pressure, it was found that if it was much below 90 millimetres of mercury, the heat did not penetrate far enough towards the middle of the furnace, whereas, on the other hand, if it much exceeds 100 millimetres—reaching, say, 150—then for the kind of charge necessary for the production of forge iron, a portion of the charge is compressed into a kernel or bar of half-fused character in the centre of the

\* *Wernländska Annaler; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lli. pp. 124–125.

shaft. The blast should have a temperature of 400° C. to 450° C. Somewhat more limestone is then necessary for the production of a good iron than is required if the furnace is worked more slowly with a colder blast. Other details connected with the construction, general arrangement, and working of such charcoal blast-furnaces are also given.

E. G. Odelstjerna \* discusses modern Swedish blast-furnace practice. Great improvements in shape and height have been made during the past twenty-five years, and the yield has increased by about 3 per cent. The average daily production has increased from 12·40 to 15·97 tons, or more than 27 per cent.

A description of the Gröndal Company's charcoal furnace has been published.†

**American Blast-Furnace Practice.**—F. L. Grammer ‡ reviews the last decade of American blast-furnace practice. A feature to be specially noted is the enormous amount of material to be handled, which tends to reduce the superintendent to the position of a "train despatcher or burden clerk." The increased subservience of the blast-furnaces to the steel plant, and of the latter to the rolling mill, is also a noticeable feature. As the result, local conditions are ignored, and mechanical appliances such as the casting machine and automatic charging apparatus are absolutely necessary. In the development of furnace practice, four incidents appear as important factors—the use of waste gas under boilers, the heating of the blast, the use of coke as fuel, and the use of Lake ores. Ten years ago furnace lines and cooling devices occupied attention; now conveyors and other mechanical improvements, by-products, and miscellaneous matters have to be considered. The handling of large quantities of ore from the mines to the furnaces, and the arrangement of the ore bins, are mentioned. Then follow skip hoists, of which three types are in vogue—Kennedy's hoist, with one skip passing the other side by side; Neeland's, with only one skip; and Rust's, with one skip passing over the other. Washed ores, valves, tap-hole guns, direct metal, casting machines, slag ladles, recording gauges, dust catchers, gas flues and mains, boilers, compressed air, steam pressure, stoves, refractory bricks, stock-line shields, by-products, flue dust, furnace workings, and other matters

\* *Teknisk Tidskrift*, vol. xxxiv. pp. 165–167.

† *Affärsvärlden*, vol. iv. p. 533.

‡ *Transactions of the American Institute of Mining Engineers*, February 1904.

1904.—i.

receive a brief notice. Stove capacity has not kept pace with blowing power, so blast temperatures have fallen and fuel consumption has risen. Silicon requirements for Bessemer work have been lower, and a brisk market has decreased the severity of demands concerning sulphur, of which there seems to be a greater tolerance, besides which it is supposed that sulphur can be kept down without manganese. The direct metal process has been extended, and molten metal is now carried as much as five miles in 20-ton ladles in Pittsburg and Cleveland. A more conservative estimate of the benefit of multiple tuyeres now prevails. The operation of drying the furnaces before blowing in has been much shortened. Explosions in furnaces using Mesabi ore are now rarer than they were, and that ore sometimes constitutes the entire burden. Gas engines worked with blast-furnace gas have been introduced at the Buffalo plant of the Lackawanna Steel Company. Coke consumption remains between 1750 and 2100 lbs. per ton, but the daily output per furnace has increased from 350 to 500 tons, and the yearly outturn from eight to eighteen million tons. Greater care has been taken in some instances to insure that the blowing engines receive air from outside the engine-house, and therefore as dry as possible.

A table is given\* showing the height and diameter of new furnaces under construction in the United States. They range from 85 by 19 feet up to 100 by 21 feet in one instance at Wharton in New York. The new furnaces in the Southern States are chiefly 85 by 19 feet, and in Pennsylvania only two are over 87 feet in height.

A view and plan of the Clairton blast-furnaces and steel plant, Pennsylvania, has been published † with illustrations of the details of ore-handling plant, bins, granulated slag conveyor, &c. The three furnaces are 85 feet in height, 21 feet diameter at the boshes, 14 feet at the stock line, and  $13\frac{3}{4}$  feet in the hearth, with twelve tuyeres. One furnace has made as much as 650 tons in 24 hours from Mesabi ores.

Some statistics have been published ‡ of the output and life of the blast-furnaces at the Ohio Works, Youngstown, Ohio. Between February 14, 1900, and November 1, 1903, three furnaces produced 1,588,323 tons. Each furnace was off, during that period, for two to three months, to be relined. The consumption of materials included

\* *Iron and Coal Trades Review*, vol. lxvii. p. 1785.

† *Iron Trade Review*, November 19, 1903, pp. 56-63.

‡ *Iron Age*, December 10, 1903, p. 3.

2,894,256 tons of ore and scale, 1,501,020 tons of coke, and 682,062 tons of limestone.

W. K. Frendenberger \* describes the electric plant at the Minnequa works, Pueblo, Colorado.

An illustrated account and plans of the La Belle iron works at Steubenville, Ohio, have appeared.† The blast-furnace plant consists of one furnace, 20 by 90 feet, with four Massick & Crooke's hot-blast stoves. A second furnace is being built. Slag is granulated in a Heyl and Patterson machine. Metal is taken direct to the steel works in 25-ton ladles. Gas is washed in Steese washers. The furnace is equipped with Brown's rotary distributor and single skip hoist. Ore and coke from the bins are handled in suspended, electrically driven, larries. Particulars are also given of the four blowing engines, pumps, &c.

A plan and illustrations are given ‡ of the blast-furnace and steel plant of the International Harvester Company at South Chicago, including a section of the proposed ore unloading and storage plant. The furnace is 85 by 19 feet, and has four Kennedy stoves, 22 by 85 feet. The double skip hoist is electrically operated, and the furnace has the Kennedy top without explosion doors. The mixers are two in number, each holding 250 tons, and are placed at such a level that the ladles do not have to be hoisted to the converters.

The erection of the Toledo furnace, Ohio, began in April 24, 1902, and the furnace was blown in on June 1, 1903. In general plan it resembles that of the South Chicago works. Two bridge unloaders are used, and the ore yards hold 160,000 tons of ore. The bins hold 350 tons of coke, 200 of limestone, and 1000 tons of ore. The furnace is 80 feet in height, with 20-foot jacketed boshes, and 13 feet at the hearth and the stock-line. It has a Kennedy top and a 9-foot bell. It is blown through sixteen 5-inch tuyeres. Four Kennedy hot-blast stoves, 22 by 92 feet, with centre combustion, are used. Three blowing engines with the air cylinders under the steam cylinders are provided. The combs of pigs are taken by electric cranes to a pig breaker of the steam-hammer type.§

A plan and fully illustrated description of the new plant of the Lackawanna Steel Company at South Buffalo, New York, has been

\* *Camp and Plant; Iron Trade Review*, October 29, 1903, pp. 54-55.

† *Iron Age*, October 8, 1903, pp. 1-8.

‡ *Iron Trade Review*, October 15, 1903, pp. 51-59.

§ *Iron Age*, October 22, 1903, pp. 22-23; *Iron Trade Review*, November 5, 1903, pp. 94-97.

published.\* A canal has been dug from Lake Erie, so that the largest ore vessels can come up to the docks. Gas engines for 40,000 horse-power are to be used, and electricity is to be employed on an extensive scale. Otto-Hoffmann ovens are to be installed. Ore is unloaded by five Hulett machines, and the ore is transferred to the stockyard and bins by travelling bridges about 85 feet high and 374 feet in length. Coke is to be brought from the ovens to the furnace skips in 6-ton tilting trucks, and the oven plant is to consist of twelve batteries of forty-seven ovens with coal-stamping machinery. The plant includes two furnaces in blast and four under construction. The existing furnaces are 86 feet high, 17 feet diameter in the boshes, 12 feet at the stock line, and 11 feet in the hearth, and have sixteen tuyeres. Four stoves are used for each furnace, 18 by 85 feet in dimensions, but the stoves for the new furnaces will be 22 by 135 feet, and the furnaces will be 94 feet in height with 24-foot boshes and 17-foot hearths.

H. Macco † describes the Edgar Thomson ironworks, which he considers typical as showing the working of the larger United States steel plants. This works possesses eleven blast-furnaces. Of these one makes ferro-manganese, its daily output being 75 tons; one makes spiegeleisen, with an average daily output of 150 tons; and nine make Bessemer iron, their average daily output being 3900 tons. The total daily output of the eleven furnaces is thus about 4125 tons. The more modern blast-furnaces are 90 feet high, 16 feet wide at the throat, 22 feet at the boshes, and about 15 feet 6 inches at the tuyeres. They are blown with twelve tuyeres, which according to requirements are from 3 to 7 inches wide in the clear. The blast pressure was about 15 lbs. per square inch, and its temperature 500° C. The average iron contents of the ore charge was 55 per cent., but some iron scrap was added, raising the total iron contents to about 56 per cent. The iron contents of the ores at the time of the author's visit was from 53 to 54 per cent., whereas it was formerly from 58 to 60 per cent. The coke consumption was 89 per cent. of the weight of pig iron made, the cost of the coke at the furnace being rather less than 14s. 6d. per ton. The limestone used amounts to 43 per cent. of the weight of the pig iron made, and its cost to about 4s. 2d. per ton. The works manager estimated the average life of a furnace at six years, and its output, without complete overhauling, at a million tons.

\* *Iron Age*, January 7, 1904, pp. 48-68; *Iron Trade Review*, December 31, 1903, pp. 40-53.

† *Stahl und Eisen*, vol. xxiv. p. 149.

H. Macco\* observes that in a visit to the United States all the blast-furnaces that he saw were steel armoured, and the furnace itself bears the charging arrangements at the throat, instead of being supported otherwise, as is customary in Germany. The furnaces have generally much larger dimensions than those in use in Germany, and the tuyere level section bears a greater ratio to that at the boshes than is usual in Germany. Similarly the tuyeres are larger and more numerous. All the more modern works strive to attain the cheapest possible transport within the works. This transportation is always effected by mechanical means, hand labour being scarcely used at all. This is carried to such an extent that the furnaces are even charged automatically, one man at the throats supervising several furnaces. As a rule, those new works which are near water transport are placed quite near it, and the author describes the conveying arrangements that are in use. The methods adopted when the works are not near water transport but on railway lines are also described. The author has verified from the works' books on several occasions a daily output of from 700 to 800 tons for a single blast-furnace.

R. Kunz† describes and illustrates a gas valve that he states is in use at American blast-furnace plants.

According to W. A. Barrows, jun.,‡ the Mesabi ores differ from the other Lake Superior ores, not only on account of their pulverulent and friable nature, but also because the fine material will not cake in the furnace. Some of the dust carried over by the blast into the dust catchers is found to be reduced iron, showing that it came from low down in the furnace. The Mesabi ores are favoured because they can be cheaply mined, a large proportion being of good chemical quality, and some even being coherent and arriving in solid form. Mixtures of Mesabi ores and siliceous ores can be worked very satisfactorily, and slips and explosions have been materially reduced by modifying the methods of charging and the top lines of the furnace. The method of charging is described, and consists in a special arrangement of the ores, fluxes, and coke in the bell. The blast should not be cut off longer than needful, as long stops lead to slips. An increased amount of fluid slag should be used, and the furnace should be kept working hot on grey iron.

An injunction has been issued by the Supreme Court of Pennsylvania restraining the emission of dust from the Eliza furnaces,

\* *Stahl und Eisen*, vol. xxiv. p. 148.

† *Ibid.*, vol. xxiii. pp. 1059-1060, with two illustrations.

‡ *Transactions of the American Institute of Mining Engineers*, February 1904.

Pittsburg, in which fine Mesabi ores are smelted. Reference is made to the briquetting of these ores.\*

The arrangement devised by F. H. Foote † and T. W. Robinson for preventing the freezing of iron ore in the bins has been in use for over a year at the South works of the Illinois Steel Company. Blast-furnace gas is burnt and circulated in jackets round the bins.

J. B. Nau ‡ states that a similar use has been made of blast-furnace gas for drying ore in the bins at some European works. Flues laid on the floor of the bins lead the products of combustion of the gases through the ore. In one case the gas entered at a pressure of  $\frac{1}{8}$  inch of water and a temperature of 441° C. into bins containing 655 tons of ore. After 36 hours the ore withdrawn had a temperature of 50° C., and had lost 53 per cent. of its moisture. Some comments are also made § on questions relating to frozen ore and coal in railway trucks.

**History of Iron.**—A concise summary of the history of iron is given by B. Neumann.||

The early history of iron is traced by J. Filoleta.¶

W. Macfarlane \*\* has lectured on British improvements in iron and steel making, giving a brief historical account of the various inventions originating in this country.

T. Mitchell †† has published a pamphlet on the Monmouthshire iron and steel trades, in which he summarises the condition of labour sixty years ago and gives reminiscences of the Chartist riots.

In the third edition of Sir Henry Yule's "Book of Ser Marco Polo the Venetian," revised in the light of recent discoveries by H. Cordier, ‡‡ the steel mines of Kerman are identified §§ with the now abandoned Parpa iron ore mines on the road from Kerman to Shiraz. Old Kerman weapons are of great beauty. Allusions to the famous sword blades of India are frequent in Arabic literature, and Pottinger names steel among the imports from India into Kerman. The *Ondanique* of Marco was no doubt a fine steel resembling the Indian article.

\* *Iron Trade Review*, March 31, 1904, pp. 42a-42b.

† *Iron Age*, October 8, 1903, pp. 14-15.

‡ *Ibid.*, October 22, 1903, p. 26.

§ *Ibid.*, February 25, 1904, p. 70.

|| *Die Metalle*, Halle, 1904.

¶ *El Minero Mexicano*, vol. xlv. p. 148.

\*\* *Journal of the West of Scotland Iron and Steel Institute*, vol. xi. pp. 115-130.

†† "Monmouthshire Iron and Steel Trade." Newport: J. E. Southall, 1904 (price 6d.).

‡‡ London: John Murray, 1903.

§§ Vol. i. p. 94.

R. B. Hodgson \* deals with Styrian steel, billets, bars, and forgings, and gives some general historical notes on the subject. The pure spathic ores are smelted with charcoal, and the resulting white iron is so treated that the total impurities often do not exceed 0.03 per cent. Thus even the high-carbon varieties may be welded.

The various medals connected with the iron industry are described by Bennett H. Brough. †

J. Florange ‡ describes and illustrates the principal medals struck at various times in France in connection with the mining industry. Seventeen relate to the iron industry.

On April 23 and 24, 1904, the Society of German Ironmasters celebrated at Düsseldorf the completion of the twenty-fifth year of its existence, and of the twenty-fifth year of the presidency of Carl Lueg. The society numbers 2957 members, and its journal, *Stahl und Eisen*, is published every fortnight. The announcement was then made that a gold medal had been instituted to be called the "Carl Lueg Medal," and to be awarded for conspicuous services to German metallurgy. The first award was made to Carl Lueg himself.

J. Hartley Wicksteed § traces the evolution of the chain from primitive ages, and discusses its various developments in modern times. He gives illustrations of an Assyrian iron chain of 880 B.C., and of the iron chains used by the Romans, and other striking photographs.

In R. A. Hadfield's paper on tungsten alloys || it is stated that the place where the brothers Elhuyar conducted their experiments in 1784 is unknown. A note appended to a Spanish translation ¶ of this paper points out that the experiments were made at the Vergara Seminary.

The blast-furnace ordinance of Queen Christina of Sweden, of November 6, 1638, has been reprinted.\*\*

A movement is on foot to erect a monument at Taunton, Massachusetts, on the site of the oldest successful iron works in America, of which some particulars are given. ††

\* Paper read before the Birmingham Association of Mechanical Engineers; *Iron and Coal Trades Review*, vol. lxviii. p. 751.

† *The Connoisseur*, vol. viii. pp. 15-17.

‡ *Annales des Mines*, vol. v. pp. 157-219.

§ *Page's Magazine*, vol. iv. pp. 100-112.

|| *Journal of the Iron and Steel Institute*, 1903, No. II. p. 20.

¶ *Revista Minera*, vol. lv. p. 117.

\*\* *Jernkontorets Annaler*, vol. lix. p. 23.

†† *Chambers's Journal*, 1904, p. 316.



C. F. Himes \* illustrates a decorated stove-plate of 1764, probably cast west of Susquehanna. Reference is made to the contribution of H. Mercer on this subject, published by the Bucks County Historical Society in America.

An illustration is given of a ruined blast-furnace built in Ohio in 1804, and some historical notes on iron manufacture in that State are collected.†

## II.—CHEMICAL COMPOSITION OF PIG IRON.

**Pig Iron Classes.**—E. Adamson‡ reviews the different classes of pig iron made in Great Britain for steel.

B. F. Fackenthal, junr.,§ comments on the 'disparity of results obtained on the analysis of pig iron, with the selection of such iron by grading only. Inasmuch as pig irons of identical chemical composition, and indeed of the same casting, may on fracture be placed in widely distinct grades, he insists on the necessity of customers always buying pig iron on chemical composition, thus eliminating the confusion which arises from pigs in different parts of the same bed being classified separately.

O. Simmersbach|| discusses the utilisation of iron ores. He gives a table showing the classes of ore suitable for blast-furnace use for the production of Bessemer pig, foundry pig, Luxemburg pig, open-hearth pig, forge pig, basic pig, spiegeleisen and ferro-silicon.

**"Glazed" Pig Iron.**—At a meeting of the Nottingham section of the Society of Chemical Industry, O. F. Hudson¶ read a paper on the subject of "glazed" pig iron. He referred to the well-known fact that in making siliceous pig iron the product has sometimes a close-grained, glittering, or "glazed" fracture instead of a coarse grey one, although of practically the same chemical composition, and made

\* *Journal of the Franklin Institute*, vol. clvi. pp. 413-415; see also *Journal of the Iron and Steel Institute*, 1903, No. II. p. 638.

† *Iron Trade Review*, March 10, 1904, p. 43.

‡ Paper read before the Sheffield Society of Engineers and Metallurgists; *Iron and Coal Trades Review*, vol. lxvii. pp. 1639-1640.

§ *Transactions of the American Institute of Mining Engineers*, Feb. 1904.

|| *Glückauf*, vol. xl. pp. 313-317.

¶ *Journal of the Society of Chemical Industry*, vol. xxiii. pp. 595-598.

apparently under exactly similar conditions. Such "glazed" iron is of less value than the open-grained variety, as it is weak and brittle, and gives unsatisfactory results in the foundry. The author then described the chemical, microscopic, and pyrometric examination of samples of glazed and open Northampton iron. The results showed that the glazed iron contained from two to three times the amount of sulphur present in the open-grained samples—a fact that would account for its unsatisfactory nature when used in the foundry. The microscope showed that the graphite in the glazed iron was of much smaller size than the graphite in the open variety. The higher percentage of sulphur was considered to be the cause of the smallness of the graphite in glazed iron, and the distinctive fracture of this iron was due primarily to the small size of the graphite flakes, since they would favour the fracture taking place through the main mass of metal rather than along those flakes.

**Gases in Pig Iron.**—E. Munker\* gives a large series of analyses of gas collected from pig iron. Some of these were from the solid metal and the remainder from the iron in its molten condition. Illustrations are published showing the methods adopted in collecting the gases. In the case of the molten metal the ingot was bottom cast, the top of the mould being closed by a tight-fitting cover through which a gas-pipe passed. The solid metal was drilled under water, an inverted funnel through which the drill passed serving to collect the gas which escaped through a tube at the top. The blast-furnace used had a capacity of 13,600 cubic feet, and the blast a temperature of 800° to 900° C. The metals examined had the following compositions :—

	Forge Pig Iron.	Steel Iron.	Spiegeleisen.
	Per Cent.	Per Cent.	Per Cent.
Carbon . . .	2.0 to 3.5	3.0 to 3.5	3.5 to 4.5
Silicon . . .	0.4 „ 2.0	0.4 „ 0.7	0.3 „ 1.0
Manganese . . .	2.0 „ 6.5	4.0 „ 6.0	11.0 „ 23.0
Phosphorus . . .	0.2 „ 0.3	0.05 „ 0.08	0.05 „ 0.10
Sulphur . . .	0.01 „ 0.06	trace „ 0.02	trace „ 0.01
Copper . . .	0.10 „ 0.30	0.10 „ 0.30	0.20 „ 0.30

The gases collected from these had compositions which varied within the following limits :—

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\* *Stahl und Eisen*, vol. xxiv. pp. 23-27, with two illustrations.

	Forge Pig Iron.	Mottled Steel Iron.	Grey Steel Iron.	Spiegeleisen.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hydrogen . . . .	9.9 to 39.0	7.8 to 12.1	18.0 to 48.0	10.2 to 52.1
Carbon monoxide . .	11.2 „ 28.2	16.6 „ 24.0	6.2 „ 19.6	10.2 „ 24.0
Carbon dioxide . .	1.2 „ 7.4	1.4 „ 3.2	0.6 „ 7.2	0.0 „ 0.4
Oxygen . . . .	0.2 „ 0.4	0.2 „ 0.4	0.2 „ 1.0	0.0 „ 0.4

The mottled "steel iron" contained 0.7 to 1.0 per cent. of silicon and 3.5 to 4.0 of manganese, whilst the grey sample contained 1.0 to 2.0 per cent. of silicon and 4.0 to 6.5 per cent. of manganese. The gases were also collected from two kinds of foundry iron, the second named being made in the same furnace and with blast of the same temperature. The first of these, to be used for casting rolls, contained:—

C.	Si.	Mn.	P.	S.	Cu.
3.5 to 4.0	1.5 to 2.5	2.0 to 4.0	0.12 to 0.16	trace to 0.02	0.15 to 0.25

This was made in a small furnace of only 2880 cubic feet capacity, and with blast of a temperature of 450° C. The second sample, made in the large furnace, contained:—

C.	Si.	Mn.	P.	S.	Cu.
3.8 to 4.2	2.0 to 3.5	0.4 to 0.8	0.4 to 0.7	trace to 0.04	trace

The gases contained:—

	No. I.	No. II.
	Per Cent.	Per Cent.
Hydrogen . . . .	18.2 to 82.9	2.5 to 10.0
Carbon monoxide . .	4.0 „ 18.8	0.4 „ 15.8
Carbon dioxide . .	0.6 „ 1.8	6.4 „ 12.2
Oxygen . . . .	0.4 „ 0.8	0.2 „ 0.8

An examination of these analyses appears to point to the composition of the dissolved gas being connected with the composition of the metal. In this connection it is necessary to distinguish clearly between the power of secretion and of absorption of gases by the iron. With regard to the latter the chemical composition of the iron, the pressure in the crucible, the greater or less over-heating of the bath of molten iron, the percentage of silicon, the fusibility of the slag, and the percentage of moisture in the blast, must all play some part; with regard to the percentage of moisture, the author found 100 grammes of the air used as blast to contain from 0.63 gramme of water when the

air was at a temperature of 17° C. in the open to 1·48 grammes when the open air temperature was 28° C. It is scarcely to be doubted that this would affect the percentage of hydrogen in the gases in the iron. Next as to the fusibility of the iron. When the various kinds of iron were poured, three distinctly different degrees of fusibility were observed. The ordinary cast iron (1) was thick-fluid; the forge and steel irons and spiegeleisen (2) were thin-fluid, and the cast iron for rolls (3) was very thin-fluid. Taking the average compositions of the gases collected from these three different types, already mentioned, it is found that there is a marked difference in the composition of the gases from the different types:—

	Hydrogen.	Carbon Monoxide.	Carbon Dioxide.	Oxygen.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
I. . . .	6·4	4·5	8·6	0·5
II. . . .	21·9	19·1	1·3	0·4
III. . . .	47·3	13·7	1·3	0·5

Dealing next with the gases collected from the solid irons the author gives details as to the volumes of gas obtained from borings of different depths, but no detailed analyses are given. It was found, however, that hydrogen was present in large quantities and carbon monoxide in small quantities in cast irons of various kinds, the proportions being apparently much the same in all of them. Unfortunately the quantities obtained from different drillings of the same specimens gave such very varying results as to prevent any general deductions. Ordinary foundry iron contained more gas than did the cast iron intended for rolls, due possibly to its being more thick-fluid.

**The Calculation of Blast-Furnace Burdens.**—J. B. Nau\* discusses the Platz method of calculating blast-furnace burdens in which silica and alumina can be mutually substituted but not alumina and lime. The composition of the pig iron is determined by the percentage of lime in the slag and not by the oxygen ratio of silica to bases. For foundry iron, Platz takes the ratio of RO bases, including manganese, magnesium, and lime, to the silica and alumina as 1·083 or 52 to 48. Taking ordinary limestone as containing 90 per cent. of available calcium carbonate, the calculation is as follows:

\* *Iron Age*, January 23, 1904, pp. 6-8.

multiply the sum of the silica and alumina by 1·083, and from the product deduct the lime, magnesia, and half the manganese; twice the result is the limestone required. In the following case, 12 per cent. is necessary :—

	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO.	MgO.	MnO.
Ore . . . .	8·0	2·0	4·0	0·5	1·0
Slag . . . .	38·4	9·6	47·2	2·4	2·4

Other examples are given.

**Zinc in the Blast-Furnace.**—J. J. Porter \* gives some notes on the behaviour of zinc in the blast-furnaces used in smelting Virginian iron ores containing 0·1 to 0·6 per cent. of zinc. After repeated descents with the charge and volatilisation, the material finally accumulates as “cadmia” somewhere in the furnace about the stock line, especially opposite the downcomer, and also in the various flues. Analyses are as follows :—

	Furnace.	Downcomer.	Flue.	Flue.
Zinc oxide . . . .	89·5	87·0	76·9	26·8
Metallic zinc . . . .	0·5	0·3	none	none
Silica . . . . .	2·9	3·4	9·8	35·9
Iron oxide and alumina . . . .	4·7	6·4	8·7	30·1
Calcium carbonate . . . .	1·5	1·9	3·7	5·6
Magnesium carbonate . . . .	0·4	0·5	0·9	1·6
Carbon . . . . .	0·5	0·5	...	...

Most of the “cadmia” accumulates in the downcomer and flues. The solid material has a specific gravity of 4·94, and a hardness on Mohs's scale of 4½. A good deal of zinc is absorbed in the brickwork, especially in the hearth, but only to a very slight degree above the fusion zone. Samples of the lining, just above the mantle, have shown 25 per cent. of zinc oxide. From one furnace, in which 28,746 tons of iron ore, containing 0·63 per cent., or 202·8 tons of zinc, were smelted, 141·3 tons were accounted for as follows: 36·5 tons in flue, 18·2 in downcomer, 16·6 in furnace deposit, all these being solid cadmia; as dust there was 18·3 tons in the flue-dust and 16 tons in the dust-catcher; absorbed in the lining was 28·6 tons and about 18·6 tons escaped with the gases, leaving 61·5 tons unaccounted for. That the zinc or “cadmia” has any effect on the iron itself seems to be more than doubtful, and even after a slip there seems to be practically no effect on the zinc contents of the slag. Its main effect is to choke

\* *Iron Age*, March 24, 1904, pp. 10-11.

the gas passages, which therefore require frequent attention, and this repays the furnace manager, as the material fetches a good price.

### III.—BLAST-FURNACE SLAGS.

**Utilisation of Slags.**—E. C. Eckel \* discusses the utilisation of iron and steel slags under a number of heads. Pozzuolanic slag cements, which are basic blast-furnace slags, pulverised, without calcination, and mixed with slaked lime, are being made by eight plants in the United States, the production in 1901 and 1902 having been 400,000 and 800,000 barrels respectively. Good results are obtained with slags containing between 26 per cent. and 32 per cent. of silica, 13 per cent. to 25 per cent. of alumina, 42 per cent. to 48 per cent. of lime, and small amounts of other constituents. To secure good hydraulic cements the slags must be cooled suddenly, and this also helps to eliminate sulphur as sulphuretted hydrogen. They are dried in Ruggles-Coles rotary driers, mixed with limes low in magnesia, and mixed and reduced in tube mills. Their specific gravity is lower than that of Portland cement, they also set more slowly, and are deficient in resistance to mechanical wear. True Portland cements are also made at two plants. Slag run into moulds for paving blocks are very durable, but slippery. Slag bricks are made from slags suitable for cement, and are said to be equal to clay bricks in crushing strength. They require less mortar. Reference is also made to highly calcareous slags used as substitutes, on the farm, for lime. Mineral wool, or silicate cotton, is then briefly dealt with. Mineral wools made from slags usually contain sulphur, the oxidation of which injures pipes or other metallic surfaces which are packed with this material. J. J. Coleman's results,† and those of Ordway,‡ as to heat-conducting power of various substances are quoted, showing slag wool to be one of the best non-conductors. Comparative conductivities: Wool, unity=1; cotton wool, 1·22; infusorial earth, 1·36; charcoal, 1·4; sawdust, 1·6; gas works breeze, 2·3; asbestos paper, 1·67; fine asbestos, 3·78; and sand, 4·77. The use of puddle slags and reheat-

\* *United States Geological Survey, Bulletin No. 213*, pp. 221–231.

† *Engineering*, September 5, 1884, p. 237.

‡ *Transactions of the American Society of Mechanical Engineers*, vol. v. p. 73.

ing cinders as paint stock, described by A. Sahlin,\* has been discontinued at Boonton, New Jersey, where it was tried in 1891. Highly aluminous slags have been used in Europe for the manufacture of alum by the Lürmann process, which consists of treating the slags with hydrochloric acid; precipitating the alumina with carbonate of lime, dissolving in sulphuric acid, and crystallising. 100 lbs. of slag containing 25 per cent. alumina yield 180 lbs. of alum and 31 lbs. of gelatinous silica. The process is in operation at Donjeux, in France, where the silica is used in improving slag cement. The use of slag for glass manufacture has not attained commercial importance. As road metal, slag macadam has proved highly successful in several parts of America. It is also used as ballast, and as a cheap material for land reclamation, and for filling up abandoned workings in mines.

E. R. Sutcliffe† describes the methods of making building bricks and paving material from blast-furnace slag. Bricks are usually made from granulated slag mixed with 6 to 10 per cent. of slag cement, hydraulic lime, or Portland cement, and simply air-hardened for three months before use. According to a new method, finely ground slag, containing 38 to 50 per cent. of lime, is compressed into bricks and allowed to harden in the air or under the influence of superheated steam. This process is described in considerable detail, and also a similar process for paving blocks. Numerous illustrations, sections, and plans are given of the plant employed in the manufacture.

J. A. Shinn‡ gives the production of blast-furnace slag as ten million tons in 1903. Of that amount, a few hundred tons were converted into slag wool, less than 75,000 tons into cement, and about a million tons were probably used as broken stone. Reference is made to the author's process of granulating molten slag with the aid of two jets of high pressure water at right angles, one slightly above the other, and comments are made on, and tests are given of, slag cements as made in the United States and elsewhere.

Since 1897 the manufacture of bricks from granulated blast-furnace slag has rapidly developed, and one firm at Osnabrück has sold presses for this purpose which are capable of making, taken together, 200,000,000 bricks per year in single shift. The newest type of

\* *Transactions of the American Institute of Mining Engineers*, vol. xx., 1891, pp. 385-394.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. xi. pp. 131-157, with three plates.

‡ *Iron Trade Review*, March 31, 1904, pp. 46-49.

press is capable of exerting a maximum pressure of 50 tons, with the result that immediately after leaving the press the brick can bear the weight of a man. A list of some of the firms making such slag bricks is given.\*

H. W. Edwards† deals with the use of concrete, made from slag and other materials, for mining and metallurgical purposes.

**Portland Cement from Blast-Furnace Slag.**—H. Detienne‡ continues§ a lengthy article on the above, discussing at length the addition of granulated slag to the calcined cement clinker, previous to grinding. He points out the great advantages of the addition of such slags in the manufacture of hydraulic cements. He gives an exhaustive series of tables showing the behaviour and strength of these cements. He also gives a number of specifications as formulated by large users of cements, and shows how closely Portland, made with the addition of blast-furnace slag, comports itself to these requirements. He points out that blast-furnace owners are, as regards sources of power, in a unique position to undertake this manufacture, as the furnace itself is a source of a large amount of energy, usually wasted, which could be applied to this purpose.

The results of elaborate tests of blast-furnace slag cement have been published by M. Gary.|| He finds that the tensile strength of slag cement mixtures decreases after storing, and recommends that slag cement should only be mixed just before use.

C. von Schwarz¶ observes that the material known as iron-portland cement has met with considerable favour in Austria.

In the manufacture of this cement from iron blast-furnace slag, not only the slag that is produced with grey pig iron can be employed but also that which is made with white iron. Indeed, the latter when properly dealt with is commercially the better of the two. The higher contents of metallic oxides lowers the sintering temperature in the clinkering process, and also leads to the cement having a higher specific gravity. H. Le Chatelier has pointed out that these metallic oxides have the further advantage of making the cement more resistant to the action of the sulphate contained in sea water, particu-

\* *Stahl und Eisen*, vol. xxiv. pp. 323-324.

† *Transactions of the American Institute of Mining Engineers*, February 1904.

‡ *Annales des Mines de Belgique*, vol. viii. pp. 406-442.

§ *Journal of the Iron and Steel Institute*, 1903, No. II. p. 648.

|| *Mitteilungen aus den königlichen technischen Versuchsanstalten*, vol. xxi. pp. 159-169.

¶ *Stahl und Eisen*, vol. xxiii. pp. 1044-1045, with one illustration.



larly magnesium sulphate. The presence of manganese oxide, if above a certain limit, was at one time considered especially dangerous as leading to changes in volume, but that is now known to be groundless. When more than 2 to 3 per cent. of manganous oxide is present the cement has a darker colour, but this is sometimes preferred, manufacturers occasionally actually darkening it by the use of coke dust or powdered coal.

**Ancient Slags.**—A. W. Comber\* gives the compositions of some ancient slags from the Island of Elba. The analyses given show 45·84 to 54·41 per cent. of iron.

#### IV.—*FOUNDRY PRACTICE.*

**Cupola Practice.**—H. E. Field† discusses various factors of economy in buying, mixing, and melting pig iron. Iron should be bought by analysis with rebates, and the prices depend on the scrap available and on the nature of the local and distant supplies and their composition. Handling of the material at the cupola is dealt with, and then attention is turned to the comparative costs of mixtures and the effect of the melting ratio.

T. D. West‡ gives some notes on gas power required for cupolas, embodying the result of some tests made with an electrically driven fan blowing a 66-inch cupola. The power used ranged from 120 horse-power at starting to 71 horse-power in normal working at 1800 revolutions, the pressure rising from 5 to 12 ounces. About 33,000 cubic feet of air are required in melting 2000 lbs. of iron in ordinary practice.

T. D. West§ also deals with castings made from direct metal and cupola metal, and states that iron plates which could easily be planed were made direct from the blast-furnace containing:—

Si.	S.	Mn.	P.
0·51	0·045	0·75	0·094

Comments are made on the behaviour of the kish.

\* *Chemical News*, vol. lxxxviii. p. 171.

† Paper read before the Pittsburgh Foundrymen's Association; *Iron Trade Review*, November 12, 1903, pp. 49-52.

‡ *Ibid.*, March 10, 1904, pp. 52-53.

§ *Transactions of the American Institute of Mining Engineers*, February 1904.

W. J. May\* describes the method of estimating the value of coke for foundry use.

**Defects in Cast Iron.**—H. E. Field† considers the causes of certain defects in cast-iron castings and their remedies. Shrinkage is inevitable in all castings, but its effect may be reduced by choosing the iron used, and by proper design of the patterns, and by a correct disposal the shrink heads and risers. These features are dealt with in some detail, but attention is more especially directed to the effect of carbon, sulphur, phosphorus, and manganese on shrinkage, blowholes, cold shuts, and weakness generally.

**Loss of Iron in the Cupola.**—O. Leyde‡ gives the results of experiments made at a small foundry to ascertain the loss of iron in the cupola which resulted from the slagging action of the sand attached to the foundry scrap returned to the furnace. This amounted to 30 or 40 per cent. of the charge. For nine days in succession the scrap was charged into the cupola with the sand attached, and then, for a period of six days, the adhering sand was removed. The results were as follows:—

	Weight of Slag.	Iron in Slag.	Silica in Slag.	Iron Charged.
	Tons.	Per Cent.	Per Cent.	Tons.
With sand adhering.	8.555	11.21	51.80	232.865
Freed from sand.	5.429	10.81	52.11	167.250

Thus for 100 lbs. of iron, when the sand was charged, 3.68 lbs. of slag were made which contained 0.412 lbs. of iron, whereas when the metal had been freed from sand the weight of slag per 100 lbs. of iron was 3.24 lbs., and this contained only 0.350 lbs. of iron. For an annual consumption of 10,000 tons of pig iron, the saving by removing the sand would be at least 10 tons of iron.

**Cleaning Cupola Gases.**—A description has appeared § of the Keyling apparatus for freeing cupola gases from dust. It consists of an arrangement by which the gases are compelled to pass through

\* *Practical Engineer*, vol. xxviii. p. 542.

† Paper read before the New England Foundrymen's Association; *Iron Trade Review*, March 17, 1904, pp. 59-62.

‡ *Stahl und Eisen*, vol. xxiv. pp. 94-103.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 29-30, with one illustration.

a series of fine jets of water. Practically the whole of the sulphurous acid contained in the escaping gases from the cupola is absorbed, while the dust is also collected.

**Fore-Hearths to Cupolas.**—F. Wüst \* discusses the advisability of the use of a fore-hearth with a cupola, and controverts Gran's denial of the value of such a fore-hearth as a mixing appliance, and declares that it had the opposite effect. It is added that the iron from the cupola ran into the fore-hearth and separated out in layers of different densities, with the result that if, in pouring the metal, it was not thoroughly stirred, the iron would be found to be of different degrees of temperature, and the castings would have very varying chemical compositions. The first series of experiments were made in a small Ireland cupola, 19·7 inches in diameter, which was charged with a mixture of 60 per cent. castings scrap, 7·5 per cent. steel scrap, 16·5 per cent. grey hæmatite pig iron, and 16·5 per cent. of white hæmatite pig iron. Eleven tappings were made and their composition was as follows :—

	Total C.	Si.	Mn.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Average . . . . .	3·51	0·49	0·22	0·139	0·147
Greatest variations from } average . . . . .	0·11	0·60	0·09	0·024	0·027
Variation per cent. . . .	3·1	12·5	40·9	17·3	18·4

The second series was made in a larger cupola, also without a fore-hearth. This was 31·5 inches in diameter, and was charged with 25 per cent. Westphalian No. III. iron, 15 per cent. mottled hæmatite iron, 20 per cent. cylinder scrap, 20 per cent. steel iron, and 20 per cent. Westphalian hæmatite iron. The cast weighed 3 tons. Similar tests to those shown above gave :—

	Total C.	Si.	Mn.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Average . . . . .	3·68	1·10	0·93	0·277	0·105
Greatest variations from } average . . . . .	0·10	0·12	0·11	0·196	0·010
Variation per cent. . . .	2·8	10·9	11·8	70·8	9·5

\* *Stahl und Eisen*, vol. xxiii. pp. 1077-1082.

A third set of tests was made in this same cupola but with a different charge, consisting of 25 per cent. mottled hæmatite iron, 15 per cent. white manganiferous iron, 10 per cent. ingot iron, 25 per cent. cylinder scrap, and 25 per cent. Westphalian hæmatite iron. The cast weighed 3 tons as before, and the composition of the metal tapped at different times was as follows :—

	Total C.	Si.	Mn.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Average	3·56	1·27	0·64	0·37	0·137
Greatest variations from } average	0·16	0·16	0·28	0·16	0·032
Variation per cent.	4·5	12·6	43·8	43·3	23·4

After these other series of experiments were made in cupolas provided with fore-hearths. The first was a cupola 27·5 inches in diameter provided with a fore-hearth. The charge consisted of 15 per cent. Westphalian hæmatite iron, 15 per cent. British hæmatite iron, 20 per cent. British No. III. iron, 25 per cent. machine scrap, and 25 per cent. castings scrap. Three tons of iron were allowed to collect in the fore-hearth, and while it was being tapped into the ladle samples were taken at intervals of a minute, eight in all. They showed :—

	Total C.	Si.	Mn.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Average	3·56	1·97	0·67	0·83	0·083
Greatest variations from } average	0·11	0·07	0·05	0·19	0·005
Variation per cent.	3·1	3·6	7·1	24·1	6·0

The second series was made with the same cupola and fore-hearth, but this time the charge consisted of 10 per cent. German hæmatite iron, 10 per cent. Coltness No. 1, 30 per cent. British No. III. iron, and 50 per cent. scrap, the cast weighing 3 tons. The results of 15 tests made as before showed :—

	Total C.	Si.	Mn.	P.	S.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Average	3·16	2·25	0·62	1·188	0·119
Greatest variations from } average	0·08	0·05	0·05	0·025	0·009
Variation per cent.	2·5	2·2	8·1	2·1	7·6

Placing these various percentage variations together for the sake of comparison it will be seen that they were as follows:—

			Total C.	Si.	Mn.	P.	S.
			Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Without fore-hearth—I.			3.1	12.5	40.9	17.3	18.4
" " II.			2.8	10.9	11.8	70.8	9.5
" " III.			4.5	12.6	43.8	43.3	23.4
With fore-hearth—I.			3.1	3.6	7.1	24.1	6.0
" " II.			2.5	2.2	8.1	2.1	7.6

Carbon shows the least variation, but this is partly due to the large quantity present, rendering errors in analysis less apparent than they are in the case of the elements present in much smaller quantities. Silicon only shows much variation in the case of the cupola without a fore-hearth. Silicon and manganese are the two elements that most readily burn out in the cupola. In a cupola without a fore-hearth and provided with a coke bottom any carbon burnt out is readily re-absorbed again. Phosphorus shows enormous variations, but in the second set of experiments in the fore-hearth cupola it will be seen that the iron in the fore-hearth had mixed very well, and the variations in phosphorus contents were relatively slight. Sulphur shows but little changes. The author therefore contends that Grau's objections to the fore-hearth are baseless.

**The Crucible Furnace in Foundry Practice.**—C. Irresberger\* observes that in no portions of foundry practice are such extreme variations observed as in connection with the working of the crucible furnaces. Ten years ago few foundries possessed a plant of this kind, but now most of the larger foundries are so provided, and those attached to the larger machine works could scarcely do without them. It is only quite recently that crucible furnaces have come into use at foundries for the melting of steel and malleable iron. The author deals first with the Piat-Baumann crucible furnace, and with others, used for the fusion of various metals and alloys, copper, bronze, &c., but adds that this furnace may also be used for the casting of grey iron. The costs, however, are greater than for a small cupola, and the iron itself is not entirely unaffected by the furnace gases. This form of furnace is not therefore applicable for iron-founding apart from occa-

\* *Stahl und Eisen*, vol. xxiv. pp. 169-175 and 253-256, with twenty-six illustrations.

sional and exceptional use. For most purposes a small cupola is satisfactory, but if it is desired to obtain a casting of as uniform as possible grain, strength, and elasticity, then it is necessary to keep the metal free from the action of the furnace gases while it is being melted, and a well-closed crucible becomes a necessity. The author then proceeds to deal with such crucible fusions, and with the furnaces and crucibles that are employed. A well-prepared graphite crucible can be made to last ten meltings—four of malleable iron and six of grey iron. Graphite crucibles give up part of their carbon to low carbon iron, especially the first time they are used, and the author has repeatedly found iron with 0·4 per cent. carbon before fusion to have increased in carbon contents after fusion to 0·65. It is therefore desirable to use the crucible the first time for grey iron. Not only does this prevent carbon passing into the iron, but the low temperature necessary for the fusion seems to do the crucible good and to increase its life. The author has used graphite crucibles supplied by eight different well-known German firms, but only those from three firms were really satisfactory. The crucibles used by the author lose about 1 lb. in weight on the first fusion, about  $\frac{1}{2}$  lb. on the second, and rather less than  $\frac{1}{4}$  lb. on the third and each subsequent fusion. Details as to fuel expenditure, cost, &c., are also given.

**Loss of Iron in the Reverberatory Furnace.**—O. Wedemeyer\* discusses the loss that takes place when iron is melted in the reverberatory furnace. It is usually assumed to be much too high. Ledebur, for instance, places it at from 5 to 8 per cent. of the weight of the metal charged, whereas it amounts really to only the fourth part of this amount. The author instances a case where a charge of 22·5 tons was melted down for conversion into large castings. Here the finished metal contained :—

Carbon.	Manganese.	Silicon.	Phosphorus.	Sulphur.
3·51	0·65	0·94	0·31	0·063

The total loss amounted to 1·26 per cent. Analyses of the various products are given. The loss is largely a factor of the lime added, too little lime meaning a considerable loss. The quantity of lime necessary is again dependent on the quantity of sand that is charged with the pig iron. Thus in one case 2 per cent. might be enough, whilst in another 4 per cent. of the weight of the iron might be needed.

\* *Stahl und Eisen*, vol. xxiv. pp. 312-313.

**Manganese Ore in the Cupola.**—Extracts are given \* from the results obtained by P. Reusch and by F. Wüst† with manganese ore as a desulphurising agent in the foundry.

**Limestone in the Cupola.**—F. Wüst‡ discusses the influence exerted by limestone in the cupola. The quantity of limestone that has to be added to the cupola charge is often guessed quite haphazard. It varies within very wide limits, from as little as 10 per cent. to as much as 35 per cent. of the weight of the coke used. It is really dependent on the ash contained in the coke, the chief reason for the addition of the lime being to slag off the ash of the coke and other slag-forming materials. Another main reason for its addition is that it shall remove the sulphur which the coke contains. This may vary from about 0·8 to about 1·3 per cent. If half this sulphur is eliminated in the upper part of the cupola, and the other half absorbed by the pig iron, it would mean that the sulphur contents of the latter by re-fusion would be increased from 0·04 to 0·07 per cent. The presence of an excess of limestone keeps sulphur out of the iron, and the author describes experiments made with a view to ascertain the ratios existing in this connection between the lime added and the sulphur removed. Analyses are given of the coke, limestone, and pig irons used and slags produced in the experiments, and analyses of the products obtained after melting these irons with different quantities of limestone. Manganese and phosphorus varied but little. The silicon varied irregularly, but the sulphur steadily decreased with each additional quantity of limestone, decreasing from 0·156 per cent. to 0·085. The first figure being obtained when the limestone used amounted to 3·3 per cent. of the weight of the coke, and the latter when it had reached as much as 30 per cent. After that the sulphur increased again to 0·10.

**Carborundum in the Cupola.**—According to F. A. J. Fitzgerald,§ carborundum cannot be used in the ladle as an addition to cast iron, but must be charged into the cupola in order to supply silicon. Its composition is approximately 62 per cent. of silicon, 35

\* *Iron Age*, November 19, 1903, pp. 14–15.

† *Journal of the Iron and Steel Institute*, 1903, No. II. p. 646.

‡ *Stahl und Eisen*, vol. xxiv. pp. 28–32, with three illustrations.

§ Paper read before the Philadelphia Foundrymen's Association; *Iron Age*, October 15, 1903, pp. 2–4.

of carbon, and 3 per cent. of iron and aluminium. For steel castings it may be placed in the ladle.

**Fluorspar in the Cupola.**—A. Lotti\* discusses the use of fluorspar in foundry practice.

**Acid-proof Castings.**—O. Nagel† states that a mixture of the following pig irons in the proportions of two of the first to one part each of the second and third resists the action of acids:—

Si.	Mn.	P.	C.
3.5	0.5	0.2	3.8
1.5	0.4	0.2	3.5
0.7	0.2 to 0.3	0.2	3.5

**Cleaning Castings with Weak Acid.**—J. L. C. Eckelt‡ observes that the cleaning of castings forms an important portion of foundry practice. In smaller works hand methods are employed, and in larger works mechanical means, such as the use of the sand-blast. Both methods have disadvantages, one taking too long to complete, and the other necessitating the use of costly appliances. A third method—that of cleaning castings by means of acid—has already been adopted at many foundries, and the author has himself erected such appliances. They have not, however, come into very general use in German foundry practice, chiefly, the author thinks, because the details of the method have not been fully understood. The author describes in the first instance an arrangement in which the casting is cleansed by means of a spray of dilute sulphuric acid. In this the casting is placed on a brick bench provided with a covering of lead, and is alternately washed with dilute acid and then with water, and is finally well washed by means of a hydrant. Care has to be taken to place the casting in such a position that it shall be equally acted on by the acid all over. This can, of course, be assisted by hand if necessary, both in the acid treatment and in the subsequent elimination of adhering sand. If allowed to remain exposed to the air for a couple of days, it becomes covered with an agreeably tinted brown-red patina. This method possesses, in the author's opinion, several advantages over the method usually employed. Labour is saved, and less tools are needed, while the general appearance of the casting is much improved. It might be contended that the acid method would

\* *Revista Minera*, vol. lv. pp. 125–126.

† *Iron Age*, September 24, 1903, p. 26.

‡ *Stahl und Eisen*, vol. xxiv. pp. 354–356, with four illustrations.



develop faulty parts in the casting, but this the author contends need never occur. It is merely a question of proper supervision on the part of the operative, and adequate washing with fresh water. In other illustrations the author shows the arrangements of such a plant for the treatment of 20 tons or more a day. The first cost of such a plant amounts to about £330. The cost of treatment is about half-a-crown a ton, as compared with eight to ten shillings in the ordinary method of treatment.

**A Large Casting.**—Illustrations are given \* of a large casting for an engine bed, measuring about  $33\frac{1}{2}$  by 12 feet, and weighing 168,000 lbs. The bottom of the mould was loam, and the sides and cope of dry sand. It was poured through five runners.

**Explosion in a Foundry.**—An account is published † of a severe explosion that occurred at a foundry at Halle. A 6-ton chilled roll was being cast for a sugar-cane mill in Java. The molten iron had been run into the mould, and a number of workmen were standing around manipulating the heavy crane above the mould. The man in charge suddenly noticed that the heavy pieces of iron which had been used to cover the mould began to move. Recognising the danger he called to the workmen to save themselves, but only some succeeded in reaching safety before the mould exploded violently. Hot gases filled the whole place, and red-hot sand and molten iron were hurled in all directions. The roof was set on fire, while three men were killed and eight severely injured. The cause of the explosion is still a mystery.

**Foundry Appliances.**—R. Moldenke ‡ describes and illustrates a large number of labour-saving appliances used in the foundry. Included are various forms of cranes, ladles, cupola-charging devices, sand mixers, and handling plant, continuous moulding tables, moulding machines, core-making machines, &c.

J. Groneman § deals with methods in use in modern foundries for driving the various machinery and tools. Power is usually obtained from a central station, and taken to the tools by various mechanical

\* *Iron Age*, October 22, 1903, p. 18.

† *Stahl und Eisen*, vol. xxiv. pp. 41-42.

‡ *Engineering Magazine*, vol. xxvi. pp. 896-924.

§ *Stahl und Eisen*, vol. xxiv. pp. 349-352.

devices, such as ropes, electricity, and water or air under pressure. The first named are being rapidly replaced by electricity. As to the compressed air or water, it is probable that the former will oust the latter in the course of time, but neither will offer any powerful opposition to electricity, and the author shows how this method of conveying power can be conveyed to the various tools that are employed in the foundry. Compressed air is similarly dealt with.

C. G. Smith\* deals with emery wheel practice in foundries for grinding castings.

A further description and plan are given † of the plant at Sharpsville, Pennsylvania, for making ingot moulds on a continuous system.

The foundry and works of Meldrum Brothers, Limited, at Timperley, near Manchester, are illustrated and described.‡

O. Leyde§ describes the foundry of Loewe & Co., Berlin, with numerous illustrations. A translation has appeared.||

Illustrations are given ¶ of the iron foundry at Borsig's works at Tegel. Four Krigar cupolas are used for melting.

The new foundry of the Westinghouse Company at Trafford City, Pennsylvania, is described and illustrated. A 100-ton casting crane forms part of the equipment.\*\*

An illustrated account has appeared †† of the Buffalo Foundry at Buffalo, New York, which is described as a modern jobbing foundry. The extensive plant of the Michigan Stove Company at Detroit is also fully described.‡‡

A plan and description is given §§ of a remodelled foundry at Newark, New Jersey.

The Sturtevant Foundry at Hyde Park, Massachusetts, is described and illustrated ||| in some detail. Plans of the core ovens and pickling department are appended.

\* Paper read before the Pittsburgh Foundrymen's Association; *Iron Trade Review*, September 10, 1903, pp. 47-48.

† *Engineering*, vol. lxxvi. pp. 576-577; *Journal of the Iron and Steel Institute*, 1903, No. II. p. 649.

‡ *Traction and Transmission*, 1903, pp. 187-195.

§ *Stahl und Eisen*, vol. xxiii. pp. 657-670.

|| *Iron Trade Review*, January 14, 1904, pp. 44-49.

¶ *Engineering*, vol. lxxvi. pp. 622-624, with plate.

\*\* *Engineering Record*, 1903, pp. 516-519.

†† *Iron Trade Review*, February 4, 1904, pp. 72-77.

‡‡ *Ibid.*, March 3, 1904, pp. 72-79.

§§ *Iron Age*, October 22, 1903, pp. 10-11.

||| *Ibid.*, October 29, 1903, pp. 21-25; *Engineering News*, vol. 1. pp. 416-418; *Iron Trade Review*, November 5, 1903, pp. 79-87.

An illustration is given \* of the Sharon Foundry, Wheatland, Pennsylvania, for heavy work.

Some illustrations are given † of the plant in the Atlas Engine Works, Indianapolis. The cupolas are concentrated in one building, and hot metal is distributed by trains of ladle trucks.

**Moulding.**—T. D. West ‡ deals with the bottoms and tops of green sand moulds. For moulding bottoms consideration is first paid to the dryness and openness of the sand and the venting. The relative fineness of the sand and the amount to which it can be compressed are discussed, and an appliance is described for testing the hardness of the ramming by means of a graduated rod pulled down by a spring balance. On the average, rammed sand weighs 100 lbs. per cubic foot, and can be suspended in bodies 14 to 18 inches square by 4 to 6 inches in depth. Illustrations are given of the use of cross bars, nails, "soldiers or gagers," &c., for suspending the sand in the cope. The dampness of the sand, and the circumstances under which drying are required, then meet attention, after which the density of the sand, venting, and risers are considered.

F. Wüst § gives illustrations showing how the moulding machine may be used in the manufacture of castings of complicated form.

A critical description of the different types of moulding machines has appeared. || The main types are grouped together, and suggestions are made as to their adoption under different conditions of use.

The method of casting in permanent moulds has long been in use for certain articles in Germany, and *Stahl und Eisen* ¶ describes them as used in connection with the casting of wire annealing pots. On a metal base plate the body of the mould is built up in good bricks or in fire-bricks, in such a way as to leave spaces between the bricks for the escape of gas. The mantle is a brick and a half thick, and is covered at the top with a cast-iron cover 1·97 inch in thickness, bolted through to the bottom plate. The inner diameter of the mantle must be about 3·16 inches wider than the pot to be cast, to admit of a marl covering of about half that thickness being placed on the brickwork. The

\* *Iron Trade Review*, December 10, 1903, p. 44.

† *Ibid.*, September 10, 1903, pp. 43-44.

‡ Paper read before the New England Foundrymen's Association; *Iron Trade Review*, November 12, 1903, pp. 43-45; November 19, pp. 51-54.

§ *Stahl und Eisen*, vol. xxiv. pp. 175-178, with eleven illustrations.

|| *Ibid.*, vol. xxiv. pp. 36-37.

¶ Vol. xxiv. pp. 352-353, with three illustrations.

protective covering must be fairly fire-resisting. For this purpose ground chamotte and retort graphite is used. The core is made by drawing a hot 0.59 inch iron mantle over the neck of a cast-iron plate and luting the two together. This sheet mantle is perforated with numerous holes, each about 0.394 inch in diameter, for the escape of gases, and it has a diameter less by about 5.53 inches than that of the core to be prepared. This core basis is then turned upside down, coated with marl, and then bound round with a 0.985 inch rope of straw or cotton. A marl coating of a similar thickness is then placed over it, and the whole allowed to dry, stirrup irons being first inserted from the outside right through until the ends show through holes in the sheet mantle, the two ends being bound together by wire. Some eight or ten such irons are inserted, and in this way the core is prevented from slipping when it dries. On the dry core the last thickness of marl is placed, dried again, and the core blacked. The arrangements used for turning the core are illustrated, and the further details of the arrangements generally described. With slight repairs as many as fifteen castings can be made without trouble in a mould so prepared. The outer brickwork suffers no damage, and can be used continuously.

E. C. Fitzgerald \* considers pattern-making in respect of the working drawings, selection of materials, machining and shaping, assembling, and finishing.

J. C. Warne† also deals with the manufacture of wooden patterns as regards their materials, the machinery used, and their users.

An illustration is given ‡ of a pneumatic sand rammer. The stroke is 7 inches, diameter of piston  $1\frac{1}{8}$  inch, weight 17 lbs., blows per minute 500, using 30 cubic feet of free air at 80 lbs. pressure.

For use in foundry practice an electric rammer has been designed by works at Jünkerath. It gives from 400 to 700 blows per minute, with a consumption of power for ordinary foundry purposes of one-quarter horse-power, but for harder moulding work this may reach 2 horse-power. The stamper weighs 143 lbs., but this weight is held in equilibrium by means of a counterbalance.§

**Malleable Castings.**—F. Wüst|| observes that experience has

\* Paper read before the Pittsburg Foundrymen's Association; *Iron Age*, December 17, 1903, pp. 30-31.

† *Ibid.*, pp. 22-23.

‡ *Iron Age*, October 1, 1903, p. 17.

§ *Stahl und Eisen*, vol. xxiv. p. 41, with two illustrations. || *Ibid.*, pp. 305-307.

shown that the pig iron to be used for malleable castings must contain only a small quantity of manganese, as this element lengthens the process by hindering the carbon changes. Numerous analyses which the author has made show that the manganese contents of the finished casting usually varies from 0.20 to 0.26 per cent., and in no case did it exceed 0.33 per cent. Phosphorus appears to be without influence on the annealing process, but if much is present it causes the finished casting to be brittle in the cold, and this is especially the case if the finished casting still contains much carbon, and sometimes as much as 2.5 per cent. will have been found to have been left behind. The largest percentage of phosphorus that the author has found in a German-tempered casting is 0.12, while usually it varied between 0.08 and 0.10. The sulphur contents of such castings varies very greatly, being dependent on whether the metal was melted down in a crucible or in a cupola. Still even such crucible-melted metal rarely contains less than 0.7 per cent. of sulphur. Usually such castings contain more than this, 0.12 per cent. being by no means exceptional, while at times it reaches as much as 0.2 per cent. This points to the difficulty which the foundryman experiences in finding a pig iron suitable for his purpose, that is, adequately low in sulphur and at a sufficiently low price. If the cupola has to be used, then the coke used is the most serious factor, and in cupola castings the author has rarely found the sulphur to be less than 0.14 per cent., while it usually varies between 0.18 and 0.25, and sometimes even reaches 0.3.

Silicon is the most important foreign element in the manufacture of annealed castings, and the success of the process and its commercially profitable character depend in the first instance on the correct percentage of silicon being present. Yet notwithstanding this most works exert no constant supervisory control at all over the silicon, but remain satisfied with the old empirical methods. In the numerous castings the author has analysed, the silicon contents have varied between the limits 0.23 and 1.03, and have usually been between 0.4 and 0.6 per cent. If too little silicon is present in a pig iron the casting made from it will have to be annealed twice, as the silicon not only renders the casting sounder, but also assists in the elimination of the carbon in the annealing process. The percentage of residual carbon that is left in the annealed casting varies enormously. Thus the author has found it to range from 0.07 to 2.54 per cent. If the annealing process has been effected at an adequately high temperature, that is to say, between 1000° and 1050° C., and the duration has been

long enough, say, not less than 100 hours, the carbon contents will have fallen almost without exception to less than 1 per cent., provided, that is, that enough silicon was present in the casting. The residuum is also in part dependent on the percentage of carbon that was originally present in the casting. Castings made from crucible-melted metal can easily be kept below 3.0 per cent. of carbon, but cupola castings usually contain from 3.4 to 3.7 per cent. High percentages of sulphur appear to slow down the annealing process, and the author, in view of these considerations, states that he considers that a pig iron that is to be used for the annealing process should contain: Total carbon, if possible, not over 3 per cent.; silicon, not much more than 1.2 per cent.; manganese, not more than 0.4 per cent.; phosphorus, not more than 0.1 per cent.; and sulphur, if possible, less than 0.05 per cent. Such a pig iron is, however, rarely obtainable, and the author gives 50 analyses of various brands of pig iron that are in use in Germany for the manufacture of annealed castings. These contain:—

	Per Cent.
Total carbon . . . . .	2.800 to 4.500
Silicon . . . . .	0.210 „ 1.970
Manganese . . . . .	0.110 „ 0.860
Phosphorus . . . . .	0.038 „ 0.155
Sulphur . . . . .	0.008 „ 0.533

Nearly half the samples contained more than 1 per cent. of silicon, but only five contained more than 0.5 per cent. of manganese. Phosphorus exceeded 0.10 per cent. in only five cases, but nearly half the samples contained more than 0.060 per cent. More than 0.100 per cent. of sulphur was present in nineteen of the castings, but 22 contained less than 0.050 per cent. A comparison of the analyses shows that low silicon often means high sulphur. As the sulphur rises so the carbon contents diminish. Usually low sulphur is accompanied by high carbon.

A committee of the American Society for Testing Materials have issued\* some proposed specifications for malleable castings. They do not recommend cupola iron. Sulphur should be below 0.06 and phosphorus below 0.225. Directions are given for making and testing the test-bars. In annealing the full heat should be continued for at least 60 hours, and the saggars should not be emptied above a black heat.

\* *Iron Trade Review*, February 11, 1904, p. 37.

## PRODUCTION OF MALLEABLE IRON.

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**Puddling.**—The puddling plant of the Clearfield Steel and Iron Company at Hyde City, near Clearfield, Pennsylvania, consists of twelve single and four double furnaces. The squeezer is 60 inches in diameter and is driven from the end of the puddle bar train.\*

**The Fusion of Malleable Iron.**—A report has been published† of some recent experiments in America upon the fusion of malleable iron in the Schwartz furnace.

**Native Iron Smelting.**—F. H. Wynne‡ describes the native methods of smelting and manufacturing iron in Jabalpur, Central Provinces, India, and gives illustrations of the furnace used, which is a modification of the third of Percy's types of Indian furnaces. It is built as a trench in a mound, and is blown with goat-skin bellows. Micaceous and ochreous hæmatites are smelted with charcoal, analyses showing as follows:—

Iron.	Silica.	Sulphur.	Phosphorus.	Water.
60·70	7·45	0·019	0·075	0·25
65·50	3·37	0·082	0·110	0·33

In Korea§ specular iron ore and limonite are common. Some of the deposits are worked by the natives, and in many places smelting furnaces can be seen. These are 6 feet high and elliptical in shape, the axes being respectively 60 inches and 32 inches. The fuel is charcoal. The metal is subjected to a double smelting. In the first, which is effected in a furnace near the mine, limestone is added to the ore, which is converted into pig iron, and the latter is sold to works at

\* *Iron Trade Review*, December 24, 1903, pp. 58-60.

† *Bihang till Jernkontorets Annaler*, 1903, pp. 401-406.

‡ *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 231-245.

§ *Iron and Coal Trades Review*, vol. lxvii. pp. 1705-1706.

a distance, generally situated near a river, in which, after a second fusion, it is transformed into ploughshares, cast-iron saucepans, &c.

**Electric Smelting of Iron Ore.**—A useful summary of the various processes of electric smelting, with comments on the claims put forward, has recently appeared,\* and is illustrated by photographic views of Stassano's 100 and 500 horse-power furnace at Darfo in 1901, Héroult's 400 horse-power furnace at La Praz in 1903, Keller's double furnace at Kerrouse in 1903, and Kjellin's furnace at Gysinge in 1903. A description of the process as carried on in these furnaces, some analyses of the raw material and products, and particulars of costs are given for each type. The Ruthenburg fritting process is also referred to, but is considered not to be of practical interest. Héroult and others at the present time have dropped the idea of smelting ore and confine themselves to melting and refining steel, producing it in some instances from raw steel or from mixtures of pig iron and scrap, &c. In conclusion, it is pointed out that the initial or capital cost of electric plant for producing say 350 tons daily, would certainly be many times greater than that of a blast-furnace.

L. Simpson † offers some comments on the above article, and states that a Canadian Commission has been appointed to investigate the electrical horse-power consumed in reducing ore, converting iron into steel, and making steel from scrap, also the cost of electrodes, repairs, hours of labour, and cost of plant. The writer also states that it may be possible to produce electricity at the cost of 15s. per annum, and that under these circumstances the cost of electric plant would compare favourably with other methods which depend on an exhaustible coal supply as compared with inexhaustible water-power.

F. Hobart ‡ reviews the recent progress in electric smelting for the production of iron and of steel.

J. B. C. Kershaw § describes the leading methods of electro-metallurgy applied to the production of iron and steel. The Héroult process, at work at La Praz, where both cast iron and steel have been made, is now practically discarded in favour of a more profitable refining operation by which scrap iron and pig iron are converted

\* *Iron and Coal Trades Review*, vol. lxviii. pp. 173-176.

† *Ibid.*, pp. 605-606.

‡ *The Mineral Industry*, vol. xi. pp. 398-404.

§ *Electrical Magazine*, 1904, p. 181.



into high quality tool steel, by what is virtually a washing-out process. This is said to be a success, and 2500 tons of high-class tool steel has been produced. Mention is made of the Keller and of the Kjellin processes, and of the Ruthenburg processes.

The electric production of steel is also reviewed by A. Neuburger.\*

P. L. T. Héroult† describes his furnace and method for steel making in the electric furnace. As employed in France and Sweden the furnace is solely employed for making tool steel from mixtures of scrap and pig iron.

C. Vattier‡ deals with the electro-metallurgical reduction of ores of iron and manganese from Chili carried out under the direction of Héroult at La Praz.

Further extracts are given§ from H. Goldschmidt's statements regarding the electric smelting of iron ores, and of Héroult's method of using the furnace for producing tool steel from scrap and other materials.

A description has appeared of the Héroult electric steel works at Kortfors and the plant erected at Skabersjö, in Scania, for generating electricity from peat.||

Further illustrations have appeared¶ of the Héroult, Keller, and Ruthenburg arrangements in an account of the progress of electro-metallurgy in 1903. Ferro-silicon and ferro-titanium are also especially mentioned.

M. Ruthenburg\*\* gives further particulars of his process, and states that the ore is agglomerated with an expenditure of 250 kilowatt-hours per ton, and that the ore is sufficiently heated for subsequent reduction. Much discussion ensued.

F. A. Kjellin†† describes the electric steel furnace at Gysinge, Sweden. This furnace is of the induction type, without electrodes, the heat being produced by the resistance to the induced currents in the metal with which the furnace is filled. The first ingot was cast in March 1900, but satisfactory results were not fully attained until May 1902. The furnace then built contained 1800 kilogrammes of steel,

\* *Zeitschrift für angewandte Chemie*, vol. xvii. pp. 104-112, 129-140.

† *Electrochemical Industry*, September 1903.

‡ *Memoirs de la Société des Ingenieurs Civils de France*, No. II. 1903, pp. 19-30.

§ *Iron Age*, September 17, 1903, pp. 2-3.

|| *Afärsvärlden*, vol. iv. p. 412.

¶ *Engineer*, vol. xcvii. pp. 127-128.

\*\* Paper read before the American Electrochemical Society, September 1903; *Iron Age*, September 24, 1903, pp. 14-16.

†† *Transactions of the American Institute of Mining Engineers*, October 1903.

from which 1000 to 1100 kilogrammes were tapped at each heat, the remainder being retained in the furnace to keep the current passing. With 165 kilowatts, or 225 electric horse-power, 4100 kilogrammes of steel ingots are produced in 24 hours, material being charged cold. The charge consists of pig iron and scrap in proportions to give the desired carbon, which is less than that in the materials charged owing to the oxidation produced by rust. Alloy steels are easily produced by adding the required materials. The loss of power has been proved experimentally to be 87·5 kilowatts, so that each kilowatt produces 53 kilogrammes of steel per 24 hours.

F. C. Perkins\* describes Kjellin's electric furnace for producing steel at Gysinge, Sweden.

G. Gin† describes his method for the electric manufacture of steel, and gives numerous calculations of efficiency and costs. It is considered that direct reduction of ores is not economical, and that the only feasible applications of electric methods are to the production of steel from iron. The furnace used comprises a number of water-cooled iron electrodes at the ends of rather long and narrow channels filled with the metal, these channels being made in a movable carriage. Either a pig and scrap or pig and ore process is adopted, the scrap or ore being added to the molten iron.

P. M'N. Bennie‡ describes the Gin process of manufacturing steel electrically.

**Electric Production of Iron Alloys.**—A. J. Rossi§ gives an account of the iron alloys and their manufacture by the method of electric smelting. Ferro-manganese, ferro-silicon, and ferro-nickel are briefly mentioned, and then more attention is given to the iron alloys containing chromium, tungsten, molybdenum, vanadium, and more especially titanium. All these alloys, except ferro-silicon, contain 3 to 8 per cent. of carbon when they are produced in the electric furnace with carbon electrodes. Of all of these ferro-titanium is the cheapest to manufacture, in view of the large quantities of titaniferous iron ore available to make this alloy, containing up to 40 per cent. of titanium. For a metal containing more than 40 per cent. richer ores are needed, but a titaniferous slag can be obtained in the electric furnace by

\* *Electrochemical Industry*, vol. i. pp. 576-578.

† *Electro-Chemist and Metallurgist*, vol. iii. pp. 572-581.

‡ *Electrochemical Industry*, vol. ii. pp. 20-24.

§ *Iron Age*, November 12, 1903, pp. 10-15.

smelting the ores at such a temperature and with such an amount of carbon that only pig iron is produced. Then this enriched slag may be used for the production of a high grade of ferro-titanium. These alloys may be made, free from carbon, by the thermite process, but the author prefers to use a bath of aluminium in the electric furnace. The coarse ore is thrown into the bath, and the reactions generate almost sufficient heat to keep the alloys fluid. In this way 650 lbs. of ferro-tungsten containing 76 per cent. of tungsten was made in 30 minutes with 11 horse-power. Other alloys have been made in a similar fashion with 70 per cent. of chromium, up to 75 per cent. of titanium, very little or no aluminium, and 0.25 to 0.75 of carbon. The use of these alloys, especially ferro-titanium, is dealt with at length for foundry and other purposes, and a number of tensile tests are given.

E. A. Sjöstedt \* describes the manufacture of ferro-nickel direct from pyrrhotite. By hand sorting this mineral can be selected from the Sudbury ore, and contains about—

Ni.	Cu.	S.	Fe.	P.
3.0	0.5	28	50	0.01

This material is roasted in a special form of shelf-furnace, and the sulphur dioxide is utilised; the residue contains 1 to 3 per cent. of sulphur. Attempts were made to smelt this material in an electric furnace of the arc type designed by the author. A pig metal was produced containing 3 per cent. of sulphur and 53 per cent. of iron, at the rate of 60 lbs. per hour, with an expenditure of 108 kilowatts, or 144 horse-power. Consequently it was decided to roast the material dead, and then to briquette it with additions of other iron ores and lime as a binding agent. Possibly these briquettes may be smelted for pig iron in the blast-furnace or used in other processes, or the material will be used for the extraction of nickel alone.

G. Gin † describes the electrolytic manufacture of vanadium and its alloys, especially with iron.

\* *Iron Age*, February 18, 1904. pp. 16-19.

† *Engineering and Mining Journal*, vol. lxxvi. p. 737.

## FORGE AND MILL MACHINERY.

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**Steel Forgings.**—T. D. Lynch \* discusses the characteristics of steel forgings, both for special and for ordinary purposes. The process of forging is first considered, and the results of tests carried out by the author are given.

J. H. Baker † also contributes some remarks upon the characteristics of good forgings.

**Design of Rolls.**—E. Kirchberg ‡ deals in detail with the design and dimensions that rolls should possess, and with a number of points connected with the actual rolling of iron and steel. The gradual rise of the modern rolling mill is in the first place briefly dealt with, and then the actual process of rolling is considered, the author dividing what then happens into three periods—(1) The metal being rolled has a greater velocity at its surface than at its centre; (2) both velocities are alike; and (3) the central portion of the metal has a greater velocity than have the outside portions. How these affect the rolling is considered, and the author then passes to the maximum permissible pressure in relation to the diameter of the rolls and of the metal being rolled, and the author gives a coefficient for this. The power possessed by the metal of changing its form at different temperatures and rolling velocities is then dealt with, and he shows that this is proportional to the thickness of the iron, and to the rolling temperature corresponding with it. How pressure affects this capacity of the metal is also considered, and the author concludes that (1) the hotter the metal the less will be the power needed to roll it; (2) the lower the pressure employed the lower will the temperature of the metal be, and the greater will be the power needed for rolling; (3) the greater the

\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xix. pp. 283-289.

† *Ibid.*, pp. 289-292.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1141-1150, with eleven illustrations.

pressure used the lower will be the machine power required. The actual minimum of power would be required when the increase in temperature of the metal due to the pressure exerted on it corresponded exactly to the loss in temperature due to radiation, &c., during the rolling process. Rolling in several heats is not advisable if it can be avoided. The length of the metal rolled is necessarily limited by its loss of heat during the rolling. The longer the length of the metal the greater is the time required to roll it with any constant velocity of the rolls, and consequently the greater is the degree of cooling to which it is exposed. To avoid this either shorter lengths must be rolled or else the speed of the rolls must be increased. In conclusion, the author considers the influence that is exerted by heat on the tensile properties of ingot iron. To ascertain this, several ingots were split into halves, of which one was heated to a high temperature and then rolled rapidly, and the other heated to a lower temperature and cooled more slowly, the rails in this latter case leaving the rolls at only a dull red heat. Tensile tests were then made with the following results:—

Metal.	Tensile Strength.	Elongation.
	Tons per Sq. Inch.	Per Cent.
Hot and rapid rolling . . . .	32·82 to 34·67	10·35 to 23·90
Colder and slow rolling . . . .	36·76 .. 37·52	7·20 .. 16·20

The hotter rolled metal is consequently the better of the two.

A translation of E. Kirchberg's paper on the design of rolls has appeared.\*

A. Sattmann† observes that the first rolling mills came into use towards the close of the eighteenth century, and the shaping of iron by means of rolling is of even earlier date. The literature of the latter portion of this subject is comparatively scanty, the first monograph on the subject appearing to be that by Peter von Tunner, in 1867. The first detailed work bearing on the subject, however, did not appear until 1900, when Geuze wrote a book on the subject—*Laminage du fer et de l'Acier*—which was published in Paris. In the same year Broyot, manager of the Differdingen rolling mills, also published a treatise on

\* *Iron and Coal Trades Review*, vol. lxviii. pp. 242-244; *Iron Age*, December 10, 1903, pp. 11-15.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 574-579, with eight illustrations; *Stahl und Eisen*, vol. xxiii. pp. 976-983, with six illustrations.

the same subject, and the latter author is now publishing an important work dealing with the subject in greater detail.

**Comparison of Small and Large Mill Plant.**—D. F. Nisbet \* makes a comparison between small and large mill plant as exemplified by an old mill and one of recent construction. It is assumed that both mills are rolling  $\frac{1}{4}$  by 8-inch tin bars at the rate of 90 tons in 24 hours in 18-inch mills, but the old mill only rolls 30-foot bars, while the modern mill makes 90-foot bars and uses labour-saving appliances. The comparison deals first with the steam-generating plant, then with coal-fired and continuous-heating furnaces, the wastage in crop ends, and the economy in labour. The points considered deal mainly with capital and other costs, and a saving is shown in the newer form of mill, but it is pointed out that added equipment is not always economical.

**Roller-Driven Tables.**—A. Kingsbury † gives the results of some tests of roller-driven tables at the Duquesne Works for the purpose of determining the sizes of the electromotors required for this class of work. The tests were made with a roller table for a 40-inch mill making slabs of 5400 to 8100 lbs., and of a skew table for a 14-inch continuous mill for rolling bars. Details are given of the sizes of the machinery, logs of various runs, ammeter and other electrical instrument readings, and the friction of the appliances considered.

**Continental Rolling Mill Plant.**—L. Baclé ‡ has prepared a detailed report on the Grey rolling mill.

K. Gruber § describes the new wire rolling mill plant that has been erected at Differdingen. The power for the new mill is supplied by a blast-furnace gas engine of 2400 horse-power. The new mill was put into operation at the end of November 1903. At the commencement of February 1904 it had reached an outturn of 60 tons per shift, and this will probably be still further increased to 70 or 80 tons per shift.

J. Hübers || observes that by a wire mill is to be understood a

\* *Iron Trade Review*, February 25, 1904, pp. 46-50.

† *Iron Age*, March 31, 1904, pp. 4-7.

‡ *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. cii. pp. 701-710.

§ *Stahl und Eisen*, vol. xxiv. pp. 377-381, with five illustrations in the text and one plate.

|| *Ibid.*, pp. 342-345, with three illustrations.

plant whose chief use is to manufacture wire of 0.2 inch diameter and upwards, which can be further drawn down if so desired to wire of smaller section. The customary arrangements of such a plant are described and the usual dimensions of the rolls are given. After describing these usual arrangements the author describes two other systems, one being a continuous wire rolling mill, only, so far as the author knows, once carried into practical effect, and that by a Rhenish works, and the other an arrangement of plant that is commonly employed in the United States.

Illustrations are published \* of an improved form of the Wikschström-Bayer wire-making machine. This splits the original rod into two, and so makes two wires at one operation without scrap.

A description and illustrations are published † of the Universal rolling mill at the Burbach works. This was exhibited at the Düsseldorf Exhibition in 1902, and put into operation at the works in the spring of 1903.

**American Rolling Mill Plant.**—Illustrations are given ‡ of a 40-inch blooming mill and of two shears built for the Illinois Steel Company.

Further illustrations, supplied by S. V. Huber, § are given of the billet mill of the Republic Iron and Steel Company at Youngstown, Ohio.

It is stated || that a plate mill with rolls 152 inches in length has been erected at Coatesville, Pennsylvania, to make plates 12 feet in width up to  $\frac{7}{8}$  inch in thickness.

In a review of the United States tin plate industry B. E. V. Luty ¶ states that a semi-continuous mill at the Monongahela Tin Plate Works, Pittsburg, has produced 75 tons in 24 hours. The plant includes a continuous heating furnace, a continuous roughing mill of five stands with tables, an automatic matcher, a continuous mill of two stands with tables, and an automatic doubler. The pack is doubled in four as it leaves the mill and then is treated in the ordinary manner. Further details of the plant are not given.

\* *Stahl und Eisen*, vol. xxiii. pp. 1060-1061, with four illustrations.

† *Ibid.*, vol. xxiv. pp. 4-9, with one plate and nine other illustrations.

‡ *Iron Trade Review*, March 24, 1904, pp. 52-53.

§ *Iron and Coal Trades Review*, vol. lxvii. pp. 1139-1141.

|| *Engineering News*, vol. 1. p. 256.

¶ *Iron Age*, January 7, 1904, pp. 86-89.

A plan is given \* of the double Garrett continuous rod mill which commenced work at the Minnequa Works, Pueblo, Colorado, in June 1903. The capacity of each mill is 400 tons in 24 hours. The 16-inch continuous mill and the 14-inch train are driven by a 40 and 72 by 60-inch tandem compound engine. The three 10-inch trains of each mill are driven by a 38 and 70 by 48-inch and a 27 and 46 by 42-inch cross compound engines. Six automatic rods serve each mill, and four automatic end discharge Laughlin furnaces supply the 6-foot 4-inch square billets. The reduction to rod 0.207 inch in diameter is made in 18 passes.

An illustrated account and plan has appeared † of La Belle Iron Works, Steubenville, Ohio. A 46-inch blooming mill is driven by a pair of 40 by 60-inch horizontal engines. Two sets of shears cut the blooms to supply the skelp mill, which is of the continuous type with a universal blooming mill driven by a 40 by 60-inch engine, and a 24-inch finishing mill driven by a 40 and 80 by 60-inch tandem compound engine. Separate mills are used for smaller sizes of skelp. Mechanical appliances are used for loading the finished skelp. Butt and lap welded pipe is made in two mills of each type, and a pipe galvanising department is added.

A plan and numerous illustrations are given ‡ of the blast-furnace, steel and rolling mill plant of the International Harvester Company at South Chicago. The blooming mill contains a 35-inch two-high reversing mill and an electric shear capable of cutting five billets at once. It is designed to make 4-inch billets,  $2\frac{1}{2}$  to 9 feet in length, for the Morgan continuous mill. The billets are reheated in two Morgan continuous furnaces having hearth areas of 38 by 10 feet and intended for 500 tons daily. The roughing mill has eight stands of 14-inch rolls, occupying a length of 40 feet, and driven by a 30 and 54 by 60-inch compound condensing engine. The finishing mill has two stands of 11-inch rolls and two of 8-inch rolls. Beyond this is an Edward's gravity cooling bed with conical feed rolls, taking bars up to 300 feet in length.

Illustrations are given § of the rolling mills attached to the blast-furnace and open-hearth steel plant at Clairton, Pennsylvania. The mill includes a blooming mill and a continuous billet mill. The

\* *Iron Age*, October 15, 1903, pp. 19-20; *Iron Trade Review*, August 27, 1903, pp. 46-50.

† *Iron Age*, October 8, 1903, pp. 1-8; *Iron Trade Review*, October 8, pp. 44-50.

‡ *Iron Trade Review*, October 15, 1903, pp. 51-59.

§ *Ibid.*, November 19, 1903, pp. 56-63.



shears can cut sections up to 28 by 8 inches hot and have a tilting table. Bins are provided to receive sheared billets for loading or transfer to the stockyard. Blooms and slabs are handled by trucks pushed hydraulically round a circular track between the loading and unloading points.

A plan and illustrated description has appeared \* of the new works of the Lackawanna Steel Company at Buffalo, New York. The rail mills are on a very extensive scale, of which brief general particulars are given. Five engines are used for driving. The two blooming mill engines are of the horizontal two-cylinder reversing type, with cylinders 40 or 41 inches by 60-inch stroke. The finishing mill engines have 48 by 54-inch cylinders and are of a similar type. Steam reversing gear for the blooming mill engines is described.

A plan and illustrations are given † of the plant of the Clearfield Steel and Iron Company at Hyde City, near Clearfield, Pennsylvania. Puddled bars are made and old rails are re-rolled.

**Gas-Driven Rolling Mills.**—Plans, sections, and other illustrations are given ‡ of the Mond gas-driven rolling-mills and power plant at the works of Monks, Hall & Co., Limited, Warrington. The present plant consists of two producers, one being held in reserve. Each is rated at 2000 horse-power, and the gas consumption is calculated at rather over 60 cubic feet per horse-power hour. Two 15-ton Darby furnaces are heated with the gas; they are 20 feet long by 5½ feet in width, and have six doors. The new mills built comprise a 16-inch cogging and a 10-inch finishing train. The finishing train has four stands of rolls and the cogging mill one; both cogging and finishing mill are driven by a 600-horse-power Premier gas engine. The driving of rolling mills even of this size by a gas engine is an innovation, for at the time the matter was decided upon there were certainly no rolling mills in existence driven by gas-engines. The gas-engine house is by the side of the roll trains, one of which is parallel to and behind the other. The cogging train is driven direct off the crankshaft carrying the rope-grooved fly-wheel, 15 feet in diameter, and the finishing train is driven off a 6½-foot pulley driven from the latter. Between the pulley and the train a Lindsay coil-clutch is placed, so that the train can readily be thrown in and out of

\* *Iron Age*, January 7, 1904, pp. 49-68; *Iron Trade Review*, December 31, 1903, pp. 40-53.

† *Iron Trade Review*, December 24, 1903, pp. 58-60.

‡ *Iron and Coal Trades Review*, vol. lxvii. pp. 1559-1563.

gear. From the finishing mill the rods go to a cooling-bed, 12 feet by 85 feet, which is of the hollow-floor type. There is in addition a saw for cutting 4-inch by 1-inch flats, which are occasionally rolled; also smaller cooling-beds, compressed-air branding machines, shears, stopper gear, and the usual appliances for weighing, bundling, and loading the rods. The 600 horse-power engine, by the Premier Gas Engine Company of Sandiacre, near Nottingham, has two cylinders  $28\frac{1}{4}$  inches in diameter, and a stroke of 30 inches. The fly-wheel, 15 feet in diameter, and weighing  $27\frac{1}{2}$  tons, is grooved for fifteen  $1\frac{1}{4}$ -inch ropes. It runs at 90 to 120 revolutions per minute.

**Electric Power in the Rolling Mills.**—E. Danielson \* describes a three-speed motor with cascade connections, used at the Sandviken works in Sweden, for driving a rolling mill. At these works 2700 horse-power is transmitted 34 miles at 20,000 volts, and transformed at the works to a periodicity of 50. Most of the motors are simple induction motors, but one is arranged with cascade connections to give speeds of 428, 375, and 333 revolutions per minute, and corresponding efficiencies of 89, 88, and 87 per cent.

An account is published of a rolling-mill plant driven by electricity that was placed in active operation at a steelworks at Schwientochlowitz in Upper Silesia in August 1903.† It comprises three 3-high trains, and deals with ingots 210 millimetres square in section. Each train has its separate electric motor, in order to make them entirely independent of each other. The breaking down rolls are provided with a 12-ton fly-wheel, the mid-train with one of 8 tons, and the finishing train with one of 5 tons. The two first-named trains have motors which will normally yield 200 horse-power, but can be worked up to a maximum of 600 horse-power. The finishing rolls have a more powerful motor. It will yield as a maximum 900 horse-power, and will usually work with 300 horse-power, this possible variation being necessary to admit of the rolling of different shapes necessitating the employment of more or less power, as the case may be. The motors and generating plant are described and a plan of the works is given.

C. Ilgner ‡ considers the way in which the variations in the load can be provided for when rolls are driven by electric power.

\* *Electrotechnische Zeitschrift*, January 21, 1904; *Electrical Engineer*, vol. xxxix. pp. 528-529.

† *Stahl und Eisen*, vol. xxiii. pp. 1372-1374, with one illustration.

‡ *Ibid.*, vol. xxiv. pp. 129-139, with six illustrations.

C. Köttgen \* deals very fully with the use of electricity as motive-power in connection with rolling mills. Working details and costs are given, and it is shown that, as compared with the use of steam, the utilisation of electric power is accompanied by a very great financial saving. It is assumed that blast-furnace gas can be used as fuel. In the discussion which ensued on the reading of his paper the author observed that from six to ten times the quantity of such gas would be needed for raising steam in boilers as is necessary for equivalent power when used direct in gas engines, and utilised as a source of electric energy.

The General Electricity Company of Berlin has issued a profusely illustrated pamphlet on electrically-driven rolling mills. Descriptions are given of twenty-seven installations.

F. Janssen † deals with the utilisation of electricity as the driving power for cogging rolls.

**Rolling-Mill Engines.**—V. E. Edwards ‡ gives some continuous indicator diagrams taken from engines before and after compounding, the engine being fitted with the Rottman valve gear. The average economy in steam consumption is found to be 18½ per cent. for light work, 30 per cent. for average work, and 45 per cent. when rolling short heavy sections.

**Generation and Distribution of Power.**—A. Rollason § discusses the economical generation and distribution of power in large works of various kinds, including iron and steel works, where 120 to 126 hours per week are run. The capital and running costs for various arrangements of steam engines with and without superheaters, gas engines with and without utilisation of exhaust, and combinations of those prime motors with electric motors, are considered. It is considered that gas power is most economical.

H. J. Waddie || deals with some of the American methods in the steel trade, and amongst many other matters describes the extensive application of electrically-driven machinery.

E. Scherenberg ¶ describes steam turbines. The largest Parsons

\* *Stahl und Eisen*, vol. xxiv. pp. 209-237, with twenty-nine illustrations.

† *Ibid.*, vol. xxiii. pp. 983-987, with five illustrations.

‡ *Iron Trade Review*, September 3, 1903, pp. 88-89.

§ *Journal of the West of Scotland Iron and Steel Institute*, vol. x. pp. 86-93, 100-115.

|| *Ibid.*, vol. xi. pp. 19-51, 71-74.

¶ *Stahl und Eisen*, vol. xxiii. pp. 1277-1280, 1332-1339, with eight illustrations.

steam turbine under construction in Germany is to afford regularly 8000 horse-power, with a working pressure of 11 atmospheres, and a steam temperature of from 250 to 300 degrees, condensation being adopted. It is anticipated that it will be able to work up to 10,000 horse-power if needed, and it is intended to utilise it for driving a dynamo of 5000 kilowatts with 5000 volts, and another of 1500 kilowatts with 600 volts.

An account is published of the Riedler-Stumpf steam turbine.\*

Sections are given † of the McDonald-McKee conveyor used at Youngstown in the Republic Iron and Steel Company's works. Two sets of rails are given an elliptical motion, so that each set alternately lifts and carries forward the material, depositing it on the other set, which repeats the action.

An account is published ‡ of cranes of various kinds and similar appliances, generally arranged for use in metallurgical works.

The new central condensation plant of the Burbach Steelworks is described and illustrated.§

Illustrations are given || of a Pelton wheel for driving a tin-plate mill at Cwm Avon, near Port Talbot, South Wales.

**Tube Rolling.**—N. Mansfield ¶ describes the manufacture of seamless boiler tubes by rolling and drawing. Billets of mild basic open-hearth steel, 3 to 4 inches in diameter and 8 to 10 feet long, are used. The composition is about—

C.	Mn.	S.	P.
0·17	0·45	0·025	0·01

The tensile strength averages 52,400 lbs., elastic limit 30,400 lbs., elongation 25 per cent. in 8 inches, and contraction of area 56 per cent. The billet is pierced by a mandrel over which it is forced by conical rollers, and then the rough tube is rolled down in the same heat over a mandrel, after which it is cold drawn.

V. Beutner\*\* describes in some detail the manufacture of welded

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 161-165.

† *Iron Trade Review*, March 3, 1904, pp. 105-106.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1065-1072, 1121-1125, with one plate and seventeen illustrations.

§ *Ibid.*, vol. xxiv. pp. 291-294, with four illustrations.

|| *Engineer*, vol. xvi. pp. 544-546.

¶ *Journal of the Society of Naval Engineers*; *Iron Trade Review*, September 17, 1903, pp. 61-62.

\*\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xix. pp. 796-834.

pipe, and also briefly refers to the cupping or drawing process and the Mannesmann and Stiefel methods. Diagrams are given to show the arrangement of the furnaces and rolls for bending and lap-welding skelp into pipe, up to 8 inches and from 8 to 24 inches in diameter. In the latter the skelp is charged into the first furnace by a machine and then drawn through scarfing rolls to the bending bench and rolls. It is reheated in a second furnace, and passed through the welding rolls, sizing rolls, and straightening rolls. The best design for the latter rolls consists of a pair of curved rolls on inclined axes. Illustrations are given of the straightening and scarfing rolls, and also plans and sections of these and the welding rolls, of the furnaces, and of the draw bench. A plan of the pipe mill of the Susquehanna Iron and Steel Company, Columbia, Pennsylvania, is appended.

F. Riffle\* gives some notes on wrought iron and steel pipe, and includes a brief but interesting account of the early methods adopted for making butt and lap welded pipe in iron and steel. A number of tests are given, and the various kinds are compared.

An enlarged edition of E. C. R. Marks' book † on tube manufacture has been published.

\* Paper read before the Pacific Coast Gas Association; *Engineering News*, vol. 1, pp. 286-289.

† "The Manufacture of Iron and Steel Tubes," 2nd edition.

# PRODUCTION OF STEEL.

## CONTENTS.

	PAGE
I. The Carburisation of Malleable Iron . . . . .	617
II. The Open-Hearth Process . . . . .	618
III. The Bessemer Process . . . . .	630

### I.—THE CARBURISATION OF MALLEABLE IRON.

**The Manufacture of Crucible Steel.**—J. M. Gledhill \* describes the manufacture and use of tool steel. In the crucible process, which is practically the only one available, it is absolutely essential to use good materials to obtain a good product. The ordinary grades or tempers and their carbon contents are as follows :—

Grade or temper number . . . . .	1.	2.	3.	4.	5.	6.
Crucible steel, carbon . . . . .	1.30	1.15	0.90	0.80	0.75	0.65
Cemented steel, carbon . . . . .	1.5	1.25	1.00	0.75	0.625	0.50

The production of blister, single and double shear steel, is briefly described, and then follows an account of the manufacture of the crucibles and of the method of melting. The additions are enumerated, the composition and prices being given for various metals and alloys containing vanadium, silicon, chromium, manganese, molybdenum, tungsten, and nickel. The methods of annealing, tempering, grinding, and generally making different forms of tools then receive attention, and particulars are given of the use of high speed tool steel.

R. H. Probert † describes the cementation process for blister steel and the production of crucible steel. Hardening, tempering, and other subsequent treatment is also discussed.

\* Paper read before the Coventry Engineering Society. A copy is in the Library of the Institute. See also the *Engineering Review*, vol. x. pp. 405–411, 497–502.

† *Engineer*, U.S.A., vol. xl. pp. 893–896.

**Thermal Balance of a Crucible Steel Furnace.**—Dealing with the paper on the calorific balance of a crucible furnace by F. Wüst,\* E. Schnatolla† gives an illustration of an arrangement he has adopted. Three such furnaces are connected together. Only the two outside furnaces are charged with coke, and the gases from these furnaces are passed into the other lying between them. From this third furnace, heated in this way by the waste heat of the furnaces on either side, the gases pass to the stack, their waste heat being utilised to heat the incoming air required for the complete combustion in the third furnace of the carbon monoxide in the gases from the side furnaces. This arrangement proved so effective that in this third furnace, heated by waste heat only, six charges, each consisting of 0.15 ton of bronze, could be melted down in the twenty-four hours, the two side furnaces heated direct taking from seven to eight charges in the same time.

## II.—THE OPEN-HEARTH PROCESS.

**Open-Hearth Furnace Design.**—L. L. KNOX‡ offers some remarks, generally condemnatory of several features of the present design of open-hearth furnaces, such as the position of the regenerators, slag pockets, ports, doors, &c.

At the Providence works at Hautmont, France, J. Puissant§ has introduced an arrangement of valves for admitting cold air to over-heated parts of the regenerators. This embodies the same ideas as those of Schönwälder, but the valves are external. Unckenbolt thinks that the arrangement is of value in increasing the life of the furnace, but further comments characterise the method as somewhat barbarous.

The relatively short life of an open-hearth furnace is due to the comparatively irregular treatment to which the gas and air conduits that lie between the producers and regenerators and the furnace on the one hand, and this and the producers and stack on the other are exposed. To avoid this, Schönwälder divided the regenerator chambers longitudinally, and provided them with separate channels containing fire-

\* *Journal of the Iron and Steel Institute*, 1903, No. II. p. 663.

† *Stahl und Eisen*, vol. xxiii. pp. 1229-1230, with one illustration.

‡ Paper read before the Pittsburgh Foundrymen's Association; *Iron Age*, February 11, 1904, p. 15.

§ *Iron Age*, January 14, 1904, p. 13.

|| *Stahl und Eisen*, vol. xxiii. pp. 1275-1276, with four illustrations.

proof valves, by the opening or shutting of which the heat point of the furnace might be changed at will. At the commencement and until the middle of the nineties the Schönwälder furnace was much discussed. Nowadays one never hears of it. Its introduction into practice was rendered difficult by its relatively high cost, and then, too, its eight or twelve valves were apt to jam tight, and so render the advantages of the furnace of no avail. To avoid these objections J. Puissant has devised a modified form of furnace which the author now describes. In the vertical channels which connect the regenerators with the furnace, clap or other valves are so inserted as to be readily opened and closed. As all open-hearths work with a stack, by opening these valves cold air can be allowed to enter the furnace, and so cool down any portion of it lying between the valve and the stack that may have been overheated. Two such valves are illustrated. They are clap valves attached to side tubes made of iron and lined, and branching from the channel. It is best to open the valves on the far side of the furnace. This method has been for some time successfully in use in connection with two open-hearths at the Providence Works at Hautmont, France. The modification is very cheap to effect, and the furnace can be altered during the Sunday rest period. It is contended that by its aid the life of the furnace is considerably prolonged. The author points out, however, that a watch is necessary to prevent the workmen opening the valves too frequently, as every time they are opened a loss of coal results.

**Steel Production without Scrap or Ore.**—O. Goldstein,\* after referring to various modern modifications of the open-hearth process, observes that not one of them completely fulfils all the requirements which the furnace method of the future will have to meet. They are enumerated as follows: (1) Production of steel with the addition of but very little or no scrap or ore; (2) a product of first-grade quality; (3) use of any kind of pig iron whatever; and (4) shortening the period needed for working off a charge. To meet these requirements the author has devised a form of furnace which represents a combination of a Bessemer converter and an open-hearth. When about to patent this the author found that in the commencement of the eighties a similar proposal had been made, and he remarks that it would be interesting to know why it has never been carried into practical effect. He thinks that possibly mechanical difficulties

\* *Stahl und Eisen*, vol. xxiv. pp. 341-342, with four illustrations.



may have then stood in the way, but considers that they have been overcome by the excellent tipping open-hearths that are now in successful use.

The author's apparatus resembles in cross-section a Bessemer converter, which can be used as such in the vertical position and as an open-hearth when placed horizontally. The method he suggests consists in placing the apparatus in this latter position, charging in the molten pig iron, turning on the blast, lifting the apparatus to the vertical position, and blowing in the ordinary way until some desired degree of decarburisation has been attained. When this point has been reached the apparatus is to be lowered to the horizontal position, the blowing stopped, and then the apparatus converted from the converter into the open-hearth by an arrangement that he illustrates and the process completed. To discharge, the furnace can then be lowered still further. The author thinks that the use of such an apparatus might enable steel to be made for five shillings a ton less than is possible by the ordinary open-hearth process.

**Gas Losses in the Open-Hearth Furnace.**—F. Schraml\* observes that the gas losses in a Siemens open-hearth furnace are due to two causes. In the first instance there is a loss at the valves when the direction is changed, due to gas passing direct to the stack unless the gas flow has been first cut off. Then again the gas from the leads and the regenerators also passes away to the stack, and to show what these losses may amount to the author takes as an example an open-hearth which is worked with 30-ton charges, the regenerator chambers being separate from the furnace. He places the cubic contents of the gas lead between the valve and the regenerator chambers at 4 cubic metres, the free space in the regenerator chambers at 25 cubic metres, and that of the channel from the regenerators to the furnace at 9 cubic metres. The temperature in the leads is estimated to be 250° C., behind the valves 400° C., on leaving the regenerators at 900° C., and in the furnace channels at 1100° C. Then estimating the sectional area at the valves at 0.6 square metre, the velocity resulting on direct connection with the stack at 4.5 metres, the duration of the reversal at 5 seconds, the average pressure at 720 millimetres of mercury, or 716 when the sucking action of the stack is in action, the author calculates that there passes direct to the stack in the 5 seconds that the reversal

\* *Stahl und Eisen*, vol. xxiv, pp. 338–341, with four illustrations.

needs, 59 cubic metres of gas, while the similar loss from the regenerator chambers and leads is 10 cubic metres, or 19 cubic metres in all, equivalent to about 4·8 kilogrammes of a coal that will yield 4·2 cubic metres of gas per kilogramme. If three reversals are made per hour the loss of coal in this way for a working year of 300 days would be as much as 105 tons.

The two sources of loss mentioned are of about equal value and need equal attention. The first loss is the less the more rapid is the reversal, and it is probably due to this that the old clap valve still finds so many to favour it, this being the most rapid reverser of the various types in practical use. The second named kind of loss depends on the length of the channels between the valves and the furnace and the free space in the regenerator chambers. It may therefore vary enormously for any given furnace charge. The example which the author took represents, he observes, a fair average. Dealing next with the ways in which these two kinds of losses may be eliminated, he shows that the first is overcome by any automatic method of closing the gas leads and channels at the moment of reversal. With regard to the second source of error, the difficulties to be overcome, while patent, are more considerable. By building the generators direct on to the furnace, as in the new form of the Siemens open-hearth, gas losses are avoided. The question whether each furnace should have its own regenerators, or whether a group of them should serve for several furnaces, finds some in favour of the one method and some who favour the other. Dealing further with the second source of loss of gas, the author shows how this so-called "back-current gas" need not be lost but may be utilised as a source of heat for the furnace. He does not consider this loss to be necessarily unavoidable.

**Additions in the Open-Hearth Process.**—W. E. Mumford\* proposes to melt ferro-silicon or silicon spiegeleisen with or without some of the ferro-manganese in a cupola, and to add it in the ladle when about half the metal is tapped from the open-hearth. By this means loss of silicon is avoided, and aluminium is not required to quiet the metal.

P. F. Dujardin† observes that the ferro-silicons made in blast-

\* *American Manufacturer*, vol. lxxiii. pp. 641-642; *Iron Trade Review*, November 26, 1903, p. 52.

† *Stahl und Eisen*, vol. xxiv. p. 53.

furnaces being comparatively low in silicon, attempts have been made to produce commercial ferro-silicons with high silicon percentages in the electric furnace. These have been successful, and ferro-silicons with from 25 to 75 per cent. are now available in quantity on the market. Ferro-silicon with 50 per cent. of silicon is especially valuable for the basic Bessemer process, and still more for use in the open-hearth, in consequence of its ready fusibility, thus enabling it to be charged direct into the ladle. It should be broken into pieces the size of a hazel nut, this being very easy to do on account of its porous structure, and then the molten steel should be charged into the ladle on top of them. The alloy melts at once and the reaction takes place immediately, while the small quantity of the alloy does not cause any appreciable cooling of the bath, the decrease of temperature its solution causes being counterbalanced by the increase due to the oxidation of the silicon. Analyses of ferro-silicon are given which show :—

Fe.	Si.	C.	P.	S.	Mn.
23.0 to 72.7	25.8 to 75.7	0.2 to 0.5	0.04 to 0.12	0.01 to 0.04	0.16 to 0.86

**Gas and Tar as Fuel.**—D. Baker \* gives an account of the use of by-product coke-oven gas and tar as fuels for the open-hearth furnace. The coke-oven plant consisted originally of 400 Otto-Hoffmann ovens with a by-product plant. The surplus gas was found to give 550 British thermal units and to contain :—

CO <sub>2</sub> .	Illuminating.	O.	CO.	CH <sub>4</sub> .	H.	N.
3.3	3.8	0.5	5.4	31.2	43.3	12.5

The use of regenerators was not possible owing to the deposition of carbon, but with the coal gas sufficient heat could not be obtained. It was therefore determined to supplement the gas with tar, for which there was not a sufficiently good market, and a special injector was accordingly devised for spraying the tar through the air-ports. Illustrations of the devices are given. The coal used contains about 2.10 per cent. of sulphur, of which 44 per cent. volatilises in coking, and the tar contains 0.25 per cent. of sulphur. Producer gas made from the coal contains :—

CO <sub>2</sub> .	Illuminating.	O.	CO.	H.	N.
6.2	0.4	0.6	22.0	6.0	64.8

Results of extended working showed that 17,127 cubic feet of gas and 584.2 lbs. of tar, or 1076 lbs. of coal, were required per ton of steel,

\* *Iron and Steel Metallurgist*, vol. vii. pp. 21-26.

and that the sulphur in the steel was far more readily controlled when coke-oven gas and tar were used.

P. Eyermann \* returns to his suggestion † of using blast-furnace gas in the manufacture of steel by the open-hearth process. Calculations are given to show the disposal of the gas from blast-furnaces making 500 tons daily, and of the cost of the process.

**Basic Open-Hearth Steel.**—G. A. Wilson ‡ prefers the basic furnace with two gas ports and two air ports at each end in preference to five or three port furnaces, as the blocks are more durable and the gas spreads better. For lining the furnace, the banks, up to a point 6 inches higher than the slag-line, are made of dolomite tapering from  $3\frac{1}{2}$  to  $1\frac{1}{2}$  feet in thickness, surmounted with  $\frac{1}{2}$  inch of chrome ore, followed by the silica lining and the roof. After drying the bottom is rammed in layers. About 5 per cent. of basic slag is used with the dolomite. For some furnaces the author uses magnesite bricks. In the Cleveland district forge and white irons of the following compositions are used with scrap to the extent of 15 or 20 per cent. :—

	Silicon.	Sulphur.	Phosphorus.
Forge . . .	1.25	0.20	1.50
White iron . .	0.90	0.35	1.50

The scrap is first charged, then  $3\frac{1}{2}$  cwt. of limestone and  $1\frac{1}{2}$  cwt. of ore per ton, and finally the pig iron. A thick slag is produced, and is thinned with 3 or 4 cwt. of calcium chloride or fluorspar, and 5 or 6 cwt. of mill scale, which should be free from sand. Skill is now required to keep the slag so as to eliminate sulphur before the carbon. When sulphur is gone, oxides are added to burn out the carbon. In order to remove phosphorus and to keep it out of the iron, it is not sufficient to have a slag rendered basic by lime alone; iron oxide must be present and the addition of iron scale produces an immediate result. Analyses of the melting and successive samples of slag and metal in one charge are given as follows :—

\* Paper read before the Civil Engineers' Club of Cleveland; *Iron Trade Review*, October 22, 1903, pp. 47-52.

† *Journal of the Iron and Steel Institute*, 1902, No. I. p. 259.

‡ *Journal of the West of Scotland Iron and Steel Institute*, vol. xi. pp. 52-58, 75-92.

Metal.			Slag.		
C.	S.	P.	Fe.	SiO <sub>2</sub> .	CaO.
0.9	0.092	0.3	3.8	16.4	50.0
0.45	0.064	0.08	6.3	13.9	52.0
0.35	0.058	0.06	6.6	13.7	48.8
0.28	0.05	0.06	8.4	12.4	53.8
0.18	0.046	0.03	9.5	11.9	49.6

Analysis of the metal as cast showed :—

C.	Mn.	Si.	S.	P.
0.155	0.435	0.004	0.042	0.019

The author also deals with the direct process and states that there are 350 and 250 ton gas-fired mixers at the Britannia and Clarence works respectively. Iron oxide and limestone are charged so as to bring the contents to an average of 0.8 of silicon and 0.15 of sulphur. After the discussion the author added that as a 350-ton tilting mixer is used, the average of the metal charged was 1.9 of silicon and 0.152 of sulphur, and of the metal tapped was 0.555 silicon and 0.078 of sulphur. A lengthy discussion was contributed to by P. N. Cunningham, T. B. Rogerson, A. B. Marquand, E. J. W. Richards, H. Crowe, A. Campion, and others. Much turned on the question of lining, the disposition of the ports, methods of charging, and materials used.

**Continuous Practice in a Fixed Hearth.**—S. Surzycki \* describes a method by which a fixed open-hearth can be made to work continuously. This he has himself introduced and had in continuous operation for over a year at the Czenstochowa works, in Russian Poland. It consists in principle in the use of two or more tap-holes, one above the other, but not lying in the same vertical plane. These discharge into a double launder, by means of which either the whole or only a portion of the furnace contents can be discharged as may be desired. The tap-holes are in a cast-iron frame which is filled in with magnesite bricks and stamped dolomite. They last exceedingly well, not being corroded even when the furnace has been several weeks at work. At first a 20-ton furnace was worked in this way, and as good results followed, a 30-ton furnace was re-built on the same lines. A still larger furnace is now under construction. The method in use consists

\* *Stahl und Eisen*, vol. xxiv. pp. 163-164, with three illustrations. Translation in the *Iron and Coal Trades Review*, vol. lxviii. p. 752.

in first charging into the furnace cold clean scrap. As soon as this has been melted, molten pig iron is run in from a mixer, or direct from the blast-furnace. When the bath has quieted down and is completely fluid the requisite quantity of ore and mill scale is added, and then a further quantity of molten pig iron. This is continued until the furnace is full. The charge is dephosphorised in the usual way by lime, and metal is tapped as soon as the desired degree of dephosphorisation has been attained. In a furnace of 25 tons to 30 tons ordinary capacity, which has an adequately deep hearth, some 45 or 50 tons of molten metal can be held, and if the tap-holes are so arranged that 25 to 30 tons of the finished charge can be tapped off, some 20 to 25 tons of metal will still be left in the furnace. The deoxidation, &c., is completed in the ladle by the use of ferro-manganese and charcoal charged into the ladle bit by bit as the metal from the furnace is being run into it. The metal produced is of excellent quality and is very quiet in the moulds. The furnace stands in need of but little repairs, which are effected in the usual way. After repairing more ore and scale is added, and then molten pig iron as before. This leads to a rapid evolution of heat in the furnace, although air and gas have been shut off. The furnace is usually kept continuously at work for one to two weeks. The pig iron in use contains from 0.6 to 0.8 per cent. of phosphorus, and the furnaces are narrow and shallow. The use of this continuous process has led to a large increase in the output of the furnaces as compared with that obtainable from them by the ordinary method of working.

R. M. Daelen \* criticises the continuous open-hearth method employed by S. Surzycki. He points out that while the results attained are of manifest importance it cannot be considered that this method can replace the Talbot process, for the increase in production attained as compared with the ordinary open-hearth process was 15 to 28 per cent., whereas in the Talbot method it is 100 per cent. Other advantages of the Talbot method are also mentioned, the author considering that that method is better than any of the others that are intended to produce similar results.

**Handling Pit Scrap.**—Illustrations are given † of the Parks method of handling pit scrap, which has been in use for over a year at the Duquesne works. An open mould is permanently placed below

\* *Stahl und Eisen*, vol. xxiv. p. 301.

† *Iron and Coal Trades Review*, vol. lxvii. p. 1008.

the tapping-hole to catch any drip after the ladle is removed. The steel thus collected is recharged into the furnace at the next heat.

**Small Open-Hearths for Castings.**—H. Eckardt \* observes in connection with the use of the small Bessemer converter for castings, that during the past thirty years he has employed some 100 small open-hearths for foundry purposes for iron and steel. At first, for commercial reasons, the furnace is usually made much smaller than becomes subsequently necessary as the market for the products extends. But it is easy to double or even treble the capacity of such a small furnace at a very slight cost when making repairs. Thus the author has built a large number of such open-hearths to take a half-ton charge, and then subsequently enlarged them so that they would take charges of 1 ton or  $1\frac{1}{2}$  ton, making, for steel casting, three casts in about 12 hours. Similarly, 1 to 2-ton furnaces have been enlarged up to 4 tons or more. If wood, peat, &c., are used in making the gas needed, then the water-vapours must be condensed before the gas is burnt. Gas from Bohemian brown coal, however, does not need such a preliminary condensation of the water-vapour. Malleable and other castings need only from three-fifths to one-half the time required for a steel cast, and labour and wages are therefore lower. The author places the cost of such furnaces at the following figures:—

Charge.				£	s.
0·5 ton, capable of being raised to 1 ton	.	.	.	51	0
1·0 " " " " 2 tons	.	.	.	58	10
1·5 " " " " 3 " "	.	.	.	73	0
2·0 tons " " " " 4 " "	.	.	.	86	10

The first costs of the metric ton of molten steel amount, the author shows, to 101·4, 90·5, 83·9, and 79·9 marks (shillings) for furnaces of the above sizes in the order in which they are shown above. This compares with 149·8 shillings per ton as quoted by Rott in connection with the small Bessemer process. Very little repairs are needed in these furnaces and they can make long runs.

**Charging Machines.**—An illustrated account is given † of various forms of charging appliances for open-hearth and other furnaces. Included are the following: Soaking-pit crane, Gutehoffnung Works, Germany; electric charging crane (five electric and one pneumatic motors), 52 ft. span, by the Morgan Engineering Co.; 5-ton vertical

\* *Stahl und Eisen*, vol. xxiv. pp. 347-348.

† *Iron and Coal Trades Review*, vol. lxviii. pp. 981-984.

charging crane, at works of the Carnegie Steel Co.; electric charging crane made by Joseph Booth & Bros., Ltd.; combined electric and hydraulic charging crane, Société Metallurgique Dnieprovienne, Russia; electrically-driven charging machine at the Burbach Works, Germany; overhead or crane-type furnace charging machine and low type furnace charging machine, at works of the Carnegie Steel Co.; Benrather charging machine; Morgan heating furnace charger; ingot carrier at the Roechling Works.

W. Küppers \* describes various modern types of open-hearth charging machines. Illustrations are given of a machine for this purpose recently designed by the Duisburg Engineering Co., formerly Bechem and Keetman, with special reference to the electric equipment.

Illustrations are given † of a number of electric travelling ingot cranes made in Ohio.

**New French Steelworks.**—The new steel-making plant at the French arsenal at Guérigny ‡ comprises two basic-lined open-hearth furnaces of respectively 12 and 18 tons capacity, served by a battery of six producers on the Poetter system. It is to provide the steel for a new armour-plate mill. A 60-ton electric travelling crane serves the whole of this plant and the casting arrangements connected with it, and it is also to act as a conveyor for the ingots to the heating furnaces, and from them to the live rollers. A Wellman charging machine is used to charge the furnaces. As only ingots of 12 to 18 tons weight are to be cast, the casting arrangements are simplified. The dimensions of the open-hearths are given. The coal used in the producers is of a very gassy character, having a high yield of volatile products, and this has necessitated modifications in many of the dimensions of the various parts of the furnaces and leads. Magnesite is used for the hearths. The plant was put in operation in November and December 1903, and some of the results attained are given. Gas analyses made during the working of the plant showed from 30 to 27 per cent. of carbon monoxide, and from 1 to 2 of carbon dioxide. A charge of 20 tons in the 18-ton furnace yielded 18·790 tons of clean ingots, and 6·1 per cent. of scrap, loss, &c., with a consumption of 0·212 to 0·220 ton of coal per ton of ingots. The charge consisted of 30 to 32 per cent. of pig iron, 20 per cent. light scrap, and 20 per cent. heavy scrap. It took 5 to 5·5 hours to work off.

\* *Elektrotechnische Zeitschrift*, vol. xxiv. pp. 989-992.

† *Iron Age*, January 7, 1904, pp. 40-44.

‡ *Stahl und Eisen*, vol. xxiv. pp. 334-337, with three illustrations.



**Russian Steelworks.**—A further album of drawings relating to the manufacture of open-hearth steel has been issued by M. A. Pavloff\* It includes a series of drawings of open-hearth furnaces from the original  $1\frac{1}{2}$ -ton experimental plant of Martin at Sireuil down to the latest developments of Wellman, Campbell, Talbot, and others, in which the charges are increased to more than a hundred times the original weight. Among them are several examples of the patterns in use in the Ural and other Russian works, mostly rated at 20 to 30 tons. Among special points may be noted the general use of magnesia, and in several cases of chrome iron ore, for the working bed, to an extent not practised elsewhere, and of petroleum residues for firing. Many new forms of reversing valves are also given, one among them being the modified Wailes valves in use at Saldensburg in the Ural, an arrangement which is very suitable for coal gas.

A. Byström † further describes and illustrates the Putiloff steelworks at St. Petersburg. The first important "modern" steelworks were founded in Mid-Russia, the oldest being the Putiloff steelworks founded in 1801, and at the present time it is not only the largest metallurgical works in the whole of Russia, but one of the largest in the world. The author gives a list of 21 of the largest Russian ironworks and engineering works, giving their date of foundation and the number of workpeople they employ. The Putiloff works employs 12,440 workpeople. Next comes the Brjansk works with 10,500 workpeople, and, third on the list, the Ssormofo works, which employs 8700 workpeople. The smallest works named employs 2000 hands. The Putiloff works cover an area of more than 247 acres, and the plant includes Bessemer shops, open-hearth furnaces, crucible steel works, foundry, rolling mills, &c., while bridge construction, cannon founding, locomotive making, &c. &c., is carried on on a large scale. The open-hearth plant comprises eleven basic-lined furnaces of 12 to 20 tons capacity. These are partly fired with gas and partly with petroleum residues or masut. Eight of the furnaces lie on one side of the casting space and three on the other. Three electric cranes of respectively 40, 20, and 5 tons are employed here. The basic hearth is made of two rows of magnesite bricks, and then on top of these a 6-inch layer of ground calcined dolomite is sintered down. Such a bottom will stand about 2000 charges. After every charge about fifteen minutes is needed for repairs, and it requires the use of cal-

\* Ekaterinoslav : S. P. Jakobleff. London : E. & F. N. Spon, 1904.

† *Stahl und Eisen*, vol. xxiii. pp. 1217-1223, with five illustrations.

cined dolomite to the extent of about 3 per cent. of the weight of the metal cast. Experiments have been made with a view to replace the dolomite by the very pure magnesite that is found in the Ufim government in the Ural, and it is probable that this will gradually replace the dolomite. The side walls of the furnaces are made of chrome iron ore, the firebridge of magnesite, and the roof of Dinas bricks. The furnace is charged with 40 per cent. Russian pig iron and 60 per cent. wrought iron and limestone, varying the latter according to the percentage of phosphorus present, which may reach to about 1 per cent. The finished metal rarely contains more than 0.05 per cent. of phosphorus, and usually only 0.02 per cent. Further details are also given, and the works and its products generally are described.

**American Open-hearth Steel Plants.**—C. W. Tideström \* describes the modern open-hearth plants in the United States, devoting special attention to new methods of constructing open-hearth furnaces.

H. Maceo,† in dealing with the making of steel in the United States, observes that he found at Homestead forty 50-ton basic-lined open-hearths, and ten 38-ton furnaces. The regenerators are not placed beneath the furnaces, but beneath the floor of the works in front of the furnaces. They are all heated with natural gas. The customary charge for an open-hearth at those works, which the author visited, appears to be 50 per cent. of molten pig iron, and 50 per cent. of scrap. The author did not see any tipping open-hearths. He was informed that the experience obtained with them had not been of a satisfactory character, and that their use was not likely to spread. In view of the relatively enormous outturn of the American blast-furnaces and steel plants, the author inquired of a number of machinery makers whether the metal produced was in all respects satisfactory, and he was very generally informed that it was extremely difficult to obtain an ingot metal of this character, and that indeed only about two firms in the whole of the United States made it.

An illustrated account and plans has appeared ‡ of La Belle iron works at Steubenville, Ohio. The works own 36 gas producers and nine 50-ton open-hearths, with electrically driven charging machines and casting ladles. The producers are charged by gravity from over-

\* *Bihang till Jernkontorets Annaler*, 1903, pp. 351-368.

† *Stahl und Eisen*, vol. xxiv. p. 151.

‡ *Iron Age*, October 8, 1903, pp. 1-8.

head coal-bins. The building is 740 by 125 feet. Soaking pits and electrically operated ingot strippers are used.

Plans, elevations, and sections are given \* of the steel plant of the American Tube and Stamping Company at Bridgeport, Connecticut. There are three 35-ton basic open-hearths, two 4-hole soaking pits, a 34-inch blooming mill. The furnace hearths are 12 by 24 feet, with large regenerators. The charge consists of 72,500 lbs., of which 50 per cent. is pig, 35 per cent. very light scrap, and 15 per cent. heavy scrap. Seventeen to eighteen heats are made weekly, generally of extra soft steel containing

C.	Mn.	P.	S.
0.08 to 0.10	0.35	0.015	0.025 to 0.035

A plan and illustrations are given † of the blast-furnace and steel plant at Clairton, Pennsylvania. The open-hearth plant consists of twelve 50-ton furnaces, fired with natural gas. A 300-ton mixer is being built, and will be heated with natural gas, so as to melt about 20 per cent. of scrap which it is intended to be charged into it. The Bertrand Thiel process is to be adopted.

W. B. Lowman ‡ describes the hospital work at Johnstown, Pennsylvania, and gives statistics of the accidents from 1887 to 1902, which occurred in various departments of steel works, and their causes.

### III.—THE BESSEMER PROCESS.

**Small Converters.**—B. Stoughton § deals with the development of the Bessemer process for small charges, and shows that all practical processes of blowing were patented by Bessemer in the early stages of his process. The form of converter, decided upon by the author for use at Newark, New Jersey, is of the usual tilting type with a removable bottom and a high stack. The capacity is two tons, and three have been built. The lining on the tuyere side is of extra thickness, and all the tuyeres are placed on one side, nearly hori-

\* *Iron Age*, November 5, 1903, pp. 25-29.

† *Iron Trade Review*, November 19, 1903, pp. 56-63.

‡ Paper read before the Medical Society of Pennsylvania; *Iron Trade Review*, November 26, 1903, pp. 45-46.

§ *Transactions of the American Institute of Mining Engineers*, vol. xxxiii. pp. 846-912.

zonally at the level of the bath. Analyses of the gas were as follows, the time being given from the beginning of the blow :—

Minutes.		CO.	CO <sub>2</sub> .	O.	N and H.
4	Flame starts . . . . .	0.0	8.2	1.1	90.7
10	Boiling . . . . .	0.3	24.3	0.4	75.0
12	Shortening . . . . .	0.4	8.8	0.2	90.6
17	After first drop . . . . .	10.7	18.0	0.2	76.1
21	End . . . . .	...	...	...	...

The pig iron contained :—

C.	Si.	Mn.	P.	S.
3.50	2.15	0.55	0.05	0.035

but all grades of iron from 1.25 to 3 per cent. of silicon have been used, though 1.6 per cent. is preferred. The iron is melted in the cupola, and including cupola losses, the waste is 15 to 17 per cent. Bottoms last 10 to 12 heats. Owing to the cheapness of starting, these small converters are only run between one and six o'clock in the afternoon, and three converters then make 20 to 30 tons.

N. Lilienberg \* also deals with small side-blown converters for use in making small castings of steel containing up to 0.25 per cent. of carbon. The field for its use is compared with that for malleable castings, drop forgings, cast iron, and other materials. The special applicability to castings for dynamos is mentioned, as the metal can be made of high permeability and low in manganese. The metal may also be suitable for centrifugal casting if that process could again come into vogue. Great uniformity can be obtained in composition. In eight consecutive charges the variations were as follows :—

C.	Mn.	Si.	P.	S.
0.24-0.28	0.75-0.97	0.21-0.29	0.048-0.053	0.024-0.039

Very mild steel can be made, down to 0.07 carbon and silicon 0.01. The pig iron used need not contain over 1.5 per cent. of silicon, as much of the heat is obtained by burning the carbon monoxide inside the converter. Sound ingots and castings are nearly always obtained. The advantages of the process are dealt with at some length, quotations being given from a paper by B. Stoughton to show, *inter alia*, the smallness of the plant required, the ease with which it can be worked, and its adaptability to multifarious requirements. On the

\* Paper read before the American Foundrymen's Association, January 6, 1904; *Iron Trade Review*, January 14, 1904, pp. 37-42.

other hand, there is very considerable waste, amounting to 14 to 17 per cent. between the pig iron and the steel at the mouth of the converters. Of this, cupola loss is about 5 per cent., and the impurities 6 per cent. At several works, the loss is stated to be as high as 30 per cent. More iron is burnt, as shown by the red smoke, but spitting of slag and metal should not occur if the process is properly worked. The waste in the lining is increased by the higher heat and the greater slagging action of the iron oxide. This is aggravated where the metal is given a rotary motion by tuyeres below the surface of the bath. Properly, the vessel should have a removable bottom, which will last 10 to 20 heats, while the top lasts 40 to 50 heats. By constant patching, however, the Tropenas may last 150 heats. Waste of metal after the blow is due to spattering during pouring, sculls, and sink heads, and gates. The latter may be reduced in size when the metal can be made very hot and quiet, but in any case a very large amount of scrap is thus made, and all projections have to be cut off as they cannot be broken off. The author places the limit of scrap in the cupola charge as 25 per cent., and disposes of the rest to the open-hearth process. As far as can be ascertained, three types of side-blown converter are in use in America: the Tropenas converter; the long tuyere form as built by B. Stoughton with one flat side and a single row of tuyeres; and the Evans-Wills form, in which the bottom is detachable and is used as the ladle.

In all side and surface-blown converters, the diameter and the depth under the tuyeres should not exceed certain limits if the action is to be thorough. If larger vessels are to be used, the cross section must be made elliptical, and more tuyeres inserted. The blast pressure is about 4 lbs. per square inch, about a tenth of that used for bottom-blown converters. Blast should strike the surface at an acute angle. Some useful historical notes are appended.

A. Simonson \* advocates the use of the Tropenas converter for the manufacture of steel castings.

A. Johansson † gives details of the construction of Tropenas converters, together with a number of data relating to their working. He points out the advantages of the Tropenas system.

Unckenbolt, ‡ referring to a former paper § of his on this subject,

\* Paper read before the New England Foundrymen's Association; *Iron Trade Review*, October 29, 1903, pp. 48-50.

† *Jernkontorets Annaler*, vol. lviii. pp. 494-524.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1227-1229.

§ *Journal of the Iron and Steel Institute*, 1903, No. II. p. 671.

observes that since it was published many have communicated with him asking for further details. The author therefore supplements his former observations. In his opinion, a converter charge of one ton is the best. It is true that it is easy to work with larger charges of two or of three tons, but if charges of less than a ton are taken there is the danger that the first charge will prove too cold, the converter lining having taken away from it a large quantity of heat, such a quantity, indeed, that it is scarcely commercially possible to blow it hot enough again by the use of coke. The converter bottom in such a case never gets really hot, as the ash keeps the heat away from it. It is only after the first heat that the converter reaches the right temperature. On the other hand, if one or two hot charges have been blown, the weight of the charge may be reduced without any danger. This is indeed always advisable where small, very thin castings have to be produced, for despite the utmost care, it takes so long to cast a ton of steel in this way that the steel may become cold in the converter. After the first charge of a ton, it is better therefore in cases like this to reduce the charge to 0·8 or 0·9 ton.

It is better to keep to the ton charge if this is possible, arranging to cast heavy and light pieces seriatim to enable this to be done. Heavier castings are better made by means of the open-hearth. To make the small Bessemer process commercially successful, it is just as well to make a few of the larger castings. Not much profit can be made from them financially, but it helps the small process. Thus of the ton charge 0·3 to 0·4 ton would be used for larger castings, and the remaining portion of the charge for the castings of smaller size. The metal from the small Bessemer converter is usually extremely hot. This leads to a subsequent tendency to crack during the contraction that results on the metal cooling and to similar faults. To avoid these it is absolutely necessary to watch the temperature of the metal that is poured from the converter, and to cool it down if necessary with some scrap, care being taken that it is not too rusty. It is necessary to insure financial success to blow as many charges as are possible in immediate succession in the same converter. Large quantities of fuel are thus saved. To save coke the author has often blown from sixteen to twenty charges of a ton each in the same converter in a day. The next day it was allowed to remain idle. As to costs, it is necessary to allow in this case 7 per cent. as the cupola loss, the iron needing to be strongly overheated, and the coke consumption is therefore naturally much

greater in the small Bessemer process than is customary in ordinary foundry practice.

A consumption of 20 per cent. of coke in the cupola should be allowed for. With regard to the loss in the converter, this depends largely on the skill of the blower. If he blows at too high a pressure and does not use the regulating valve, the loss may be enormous, the quantity blown out of the converter being then very great. The loss, too, is dependent on the form of the converter itself and the arrangement of the tuyeres. If the converters are too short the metal blown out is too great, while if they are too long it is difficult to recognise the beginning and the end of the operation. If, again, the iron charged into the converter is too cold, heavy losses ensue. If it is too high in silicon much metal will be blown out, and other points have also to be considered. The author averages the loss in the converter at about 8 per cent., or with the 2·5 to 3·0 per cent. of the additions added for deoxidation and recarburising, to 10·5 or 11 per cent. in all. According to the shape, size, &c., of the casting to be made, from 10 to 60 per cent. of scrap may be used. The author gives a balance-sheet showing the details of the cost of the process. The molten steel as poured from the converter costs, according to this calculation, 93s. per ton.

C. Rott\* discusses the use that is made of the small Bessemer converter in Germany, and observes that the remarks made by Unkenbolt† as to its application in Belgium largely apply to German practice also. For a long time past the author has himself been engaged in connection with the use of converters, varying in capacity from three-quarters of a ton to a ton and a half. At the close of 1900 there were in Germany four plants provided with small Bessemer converters. These were at Güstrow, Chemnitz-Altdorf, Schaffhausen, and at Hagen in Westphalia. These employed converters on the Robert, Tropenas, and Walrand systems, but at Chemnitz-Altdorf a local type of converter was employed resembling those of Robert and Tropenas. In addition to three small experimental plants at Augsburg, Friedland in Austrian Silesia, and at Ekaterinoslav, which are to be built later on, other such small Bessemer plants have been built in Germany to the author's designs at Stettin-Bredow and at Dessau. Other such plants are in process of erection at Poremba and in Saxony, while others again, though of

\* *Stahl und Eisen*, vol. xxiii. pp. 1403-1404.

† *Journal of the Iron and Steel Institute*, 1903, No. II. p. 671.

a different type, are being built at Eberswalde and at Bremen. Pig iron is blown at 2.5 to 3.0 per cent. of silicon, 0.04 to 0.06 of sulphur, 0.8 to 1.2 of manganese, and 0.06 to 0.08 of phosphorus. British iron is also used in the north. A high phosphorus contents does not hurt, provided an adequate percentage of manganese is also present, or this must be added. A high contents of graphite slows down the decarburising period, and may lead to an iron which is less hot and less thin-fluid than it should be.

With reference to the cost of the process the author gives a tabular statement dealing with the various items of cost separately, and showing that the cost for one metric ton of finished steel castings amounts to 286.3 shillings (marks). This is for a works making about three tons of castings in the working day. The general average cost of such a works amounts to from 250 to 290 shillings per ton according to the varying local condition, and where small-sized or medium-sized castings are made.

**Converter Accessories.**—O. H. Glasser\* gives some particulars of appliances used in connection with converters used for matte, and refers to cranes, lifting appliances, ladles, &c.

A. Dondelinger† describes and illustrates the arrangements connected with the use of a newly-erected electric crane at the basic Bessemer steelworks belonging to the Compagnie des Forges de Châtillon Commentry et Neuves Maisons. The works possesses three basic-lined Bessemer converters, each of 18 tons capacity, and one pig iron mixer of 220 tons capacity. A fourth converter and a second mixer will probably be added to the plant later on. The other arrangements are briefly referred to, and then this newly-erected crane is described and illustrated.

**American Bessemer Plant.**—A plan and illustrations have appeared‡ of the new plant of the Lackawanna Steel Company at Buffalo, New York. The Bessemer plant includes four 12-ton converters arranged in pairs. The cupola house contains eight iron cupolas, 9 by 30 feet, and four spiegel cupolas, 7 by 30 feet. The vessel floor is 13½ feet above ground level, the tapping floor 11 feet above the vessel floor, and the charging floor 30 feet above the tapping

\* *Engineering and Mining Journal*, vol. lxxvii. pp. 519-522.

† *Stahl und Eisen*, vol. xxiv. pp. 16-22, with eleven illustrations.

‡ *Iron Age*, January 7, 1904, pp. 48-68; *Iron Trade Review*, December 31, 1903, pp. 40-53.



floor. A 300-ton oil-fired mixer is to be built. Particulars are given of the sizes of the buildings and other details.

An illustration is given \* of the Bessemer department in the works of the International Harvester Company at South Chicago. There are two 10-ton vessels supplied from two 250-ton mixers of the tilting spherical type. Sections of these are given. They are placed at such a level that the metal does not have to be hoisted to the converters.

Some statistics have been published † of the production of the Bessemer plant of the Ohio Works at Youngstown, giving the records obtained and the total products.

**Basic Bessemer Slag.**—A method by which basic slag is rendered suitable for manurial purposes by treatment with steam is discussed by Müller.‡ The process has rapidly been taken up on a large scale. Analyses quoted by the author show that the material so treated contains at the most 6 per cent. of moisture. It has, however, this advantage over the ordinary ground slag, that it is much easier to spread, and does not blow away so easily. Other samples more perfectly dried were less satisfactory in this respect, but the percentage of soluble phosphoric acid had considerably increased. An interesting point in connection with this is that the practical results obtained with the once-sifted steamed slag have been much better than similar results obtained with the slag ground in the ordinary way, although the latter contained 6 to 7 per cent. more soluble phosphoric acid. Analysis of such slag gave the following percentage results :—

Moisture.	Loss on Ignition.	Total Phosphoric Acid.	Soluble Phosphoric Acid.	Fine Material.
0·0 to 5·90	0·0 to 2·41	14·92 to 17·52	10·87 to 11·97	51 to 67

The soluble phosphoric acid was thus about 70 per cent. of the total phosphoric acid present.

In the process devised by Müller§ for treating phosphoric slag from the basic process, it is subjected to the action of superheated steam for a few hours, and that causes it to fall into a fine powder by slaking the lime. Grinding is thus dispensed with, and the phosphoric acid, soluble in citric acid, is at the same time increased by 2 to 2½ per cent.

\* *Iron Trade Review*, October 15, 1903, pp. 54-55.

† *Iron Age*, December 10, 1903, p. 3.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1420-1421.

§ *Engineer*, vol. xevii. p. 22.

**Mixed Bessemer and Open-Hearth Process.**—Experiments have been made on the lines of the mixed Bessemer and open-hearth process, which has been practised in Europe at Witkowitz and elsewhere, at the basic open-hearth steel plant of the Tennessee Coal, Iron, and Railroad Company at Ensley, Alabama.\* Hot metal from the blast-furnaces was first blown in a small Bessemer converter before being introduced into the open-hearth furnace, and a large converter is now in operation. The hot metal from the furnaces is taken directly to the converter, and after the customary blowing process, in which much silicon is burned out, is poured into the open-hearth furnaces. Owing to the preliminary blow, it is expected that the metal will take only about half the time in the open-hearth furnace, and the open-hearth furnaces will have their output very largely increased. The preliminary reports are satisfactory.

\* *Iron Trade Review*, February 25 1904 p. 35; *Engineering and Mining Journal*, vol. lxxvii. p. 399.

## FURTHER TREATMENT OF IRON AND STEEL.

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**Production of Sound Ingots.**—J. Riemer\* describes a new patent process for increasing the density of steel ingots, and for the prevention of pipe, which depends upon preventing a top crust on the ingot until the metal below has become solid. The idea is by no means new, but the method by which the object is effected is a novel one. Investigations have shown that the ingot metal requires to be heated far above melting point, in order to keep the upper part of the ingot in the liquid state for a sufficient length of time. According to the author, the pipe cannot form, and the gases evolved during the cooling of the lower part can always find their way out through the layers of liquid metal. Only when the topmost layers finally cool do a few blowholes and cavities form in them. The essential part of the process consists in the preheating of air and producer-gas in a special heating apparatus, and in passing the heated mixture through a burner inserted in a cover on the top of the ingot-mould, so that the flame strikes downwards upon the surface of the metal. Illustrations of the arrangement are given, showing the cover with the burner, and the passage also provided in the cover for leading off the waste products. The heat of these is utilised in preheating the gas and air. In dealing with large ingots of 20 to 60 tons, it is claimed that this process is much more rapid in its action than that of compressing the ingot while solidifying in the mould. The pressure must be applied throughout the whole time of solidification; while with this system of heating up the head of the ingot the gas can be shut off as soon as the bottom and sides are well set, as the metal at the top remains liquid long enough to enable it to fill any cavity due to shrinkage. In the case of a 24-ton ingot the gas was turned on for

\* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1675-1680.

one and a quarter hours, after which the ingot was allowed to cool down undisturbed. The porous part was confined to a small area high up in the head, and when cut off was found to represent about 7 per cent. of the total weight. Analyses from various parts of the ingot show that the homogeneity is good, and that no segregation of the carbon, manganese, or phosphorus took place.

In another paper J. Riemer\* reviews the methods for the production of sound steel ingots. The methods in use for producing a sound ingot in casting are mentioned. After cooling, the head, for instance, may be removed, leaving a sound remaining portion. This may mean a loss of from 15 to 30 per cent. of the weight of the ingot, and in steel castings 50 per cent., or even more. This method is therefore a costly one. The exertion of pressure on the metal in the mould is referred to, and it is pointed out that this necessitates the use of costly apparatus, and this, too, with but a small output. The process is not, therefore, commercially satisfactory. The older method, chiefly in use in the United Kingdom, consists in exerting pressure on the top of the steel. This has not only the above-mentioned disadvantages, but it also tends to prevent the escape of gases from the metal. The so-called wire-drawing method more recently proposed by Harmet, who exerts the pressure on the steel from below instead of from the top, is free from many of these objections, but is still costly. The author describes and illustrates the method devised by himself, which consists in keeping the upper portion of the metal molten in a preheated mould by the use of a gas jet under a cover.

J. Riemer's method of producing sound ingots by keeping the top molten as long as possible is also described † in translations of the above paper.

**Gas Welding and Heating Furnaces.**—T. Stapf ‡ observes that the 40,000,000 tons of finished iron and steel that is now made each year must pass at least once, and usually several times, through heating furnaces of one kind or another. Any improvement in such furnaces, and in particular any cheapening of the heating process, must consequently be of far-reaching importance. The actual cost of treatment in such a furnace is dependent in the first place on the fuel burnt in it,

\* *Stahl und Eisen*, vol. xxiii. pp. 1196–1203, with fourteen illustrations.

† *Iron and Coal Trades Review*, vol. lxvii. pp. 1776–1778; *Iron Age*, December 24, 1903, pp. 29–30.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1378–1392, with six illustrations.

the loss in oxidation, the wages spent, and on other working charges. The two first-named, however, may reach as much as 80 per cent of the total cost. The author, in considering furnaces of this type, consequently deals chiefly with these items of cost. The forms of heating fires in use in bygone times are first briefly mentioned. The fuel consumed was always very high in proportion to the weight of iron heated, and the available heat utilised rarely exceeded 5 per cent. On the other hand, the loss of iron was usually low, as carbon was present in excess, and each piece of iron removed as soon as it was ready. These fires gave way to reverberatory furnaces with larger outputs, but these direct-fired furnaces used an excessive amount of fuel, and the loss of metal was usually very considerable. Next came the use of gas-fired furnaces, and regenerator chambers began to be employed. The author sketches the improvements that have been gradually introduced into these and draws attention to the relative advantages possessed by long and relatively narrow hearths over those which are short and broad, as compared with their length. The length of the hearth should be dependent on the quantity of gas that is to be burnt in the furnace, and inversely the gas used should be dependent on the length of the hearth, in order to avoid too much heat passing away with the waste gases. In order to insure a proper distribution of the heat within the furnace, the author recommends the use of divided beds to reduce the loss of iron. Numerous results are given that were obtained in practice with gas-fired welding and heating furnaces of the Stäpf type.

**Cold Working of Steel.**—P. Möller\* gives an account of his observations during a visit to the United States. Among other things he witnessed the performance of a Bickford drilling machine with which a 4-inch hole was bored through a  $4\frac{1}{2}$ -inch plate of 0.45 carbon steel in 3.67 minutes. The construction of this and other types of drilling tools is referred to. He also describes the cold rolling and hammering of steel. Jones and Laughlin's process for the cold rolling of round bars is dealt with. The Pressed Steel Car Company also cold-roll the journals of railway axles, after turning them. This process removes all tool marks and hardens the surface, giving it a high polish at the same time. Other makers of rolling stock treat axle journals by similar methods. A swaging hammer for drawing down bars or

\* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1778-1781.

reducing the ends of tubes by cold-hammering is also described, and is said to be capable of giving 2000 to 4000 blows per minute.

**Doors for Heating Pits.**—T. H. Lauder \* describes various forms of doors for gas-fired heating pits, especially with reference to their construction for facilitating the handling of the doors themselves and of the ingots or slabs in the pits.

**Steel Castings.**—A short account of Hadfield's steel foundry at the East Hecla Works, Sheffield, has been published, in connection with a visit of the students of the Institution of Civil Engineers. †

An illustration is given ‡ of a hydraulic cylinder cast in steel, 27 feet in length, with walls 2 inches in thickness. It withstood a pressure of 3 tons per square inch.

W. P. Barba§ discusses the widening use of steel castings in the United States.

L. L. Knox|| contends that steel castings made from the basic furnace are equally as good as those made from an acid furnace.

**Preventing Blowholes in Ingots and Castings.**—F. C. Weber ¶ deals further with the use of titanium and boron as additions to steel for the prevention of blowholes in ingots and castings. In one instance  $\frac{1}{2}$  to 1 lb. of ferro-titanium-boron and 2 to 5 lbs. of a 20 per cent. ferro-titanium is used per ton. The titanium may be introduced by the aid of thermite, but boron should also be added, as the slags are more fusible and free themselves more easily from the molten metal.

**Use of Thermite for Castings.**—H. Goldschmidt \*\* has given further particulars of the use of thermite in its various forms as an addition to the metal in the ladle, the thermite being enclosed in a box and immersed in the bath. These boxes of thermite have also been placed in the moulds or risers where the metal is likely to chill or run cold. In this way large and intricate castings are improved.

\* *Journal of the West of Scotland Iron and Steel Institute*, vol. xi. pp. 107-114.

† *Engineer*, vol. xcvii. p. 414; *Engineering*, vol. lxxvii. p. 577.

‡ *Engineering*, vol. lxxvi. p. 528.

§ *Cassier's Magazine*, vol. xxv. pp. 337-344.

|| Paper read before the Pittsburg Foundrymen's Association; *Iron Trade Review*, February 4, 1904, pp. 106-107.

¶ *Iron Age*, November 12, 1903, pp. 6-7; *Journal of the Iron and Steel Institute*, 1903, No. II. p. 664.

\*\* Lecture at the Columbia College, New York; *Iron Age*, November 19, 1903, pp. 16-17; see also *Journal of the Iron and Steel Institute*, 1903, No. II. p. 674.

The applications of thermite in metallurgical engineering are described by C. V. Boys.\*

E. Guarini † describes the applications of thermite for various purposes of welding.

E. Stütz ‡ describes the applications of thermite, especially for welding rails, pipes, &c.

B. P. Caldwell § describes the use of thermite for the production of metals free from carbon and for the generation of high temperatures.

C. E. Masterman || states that the metal produced by thermite is of the nature of mild steel, and has an elastic limit of 24 tons per square inch and an elongation of 19 per cent.

The Goldschmidt welding process has been successfully applied to the repairing of the broken stern-post of the steamship *Sebenico*. Illustrations of the method of carrying out the work are given. ¶

**Electric Welding.**—An article has been published \*\* on electric welding in which some new machines for welding chains are described.

L. Leroyer †† gives a resumé of methods for the autogenetic soldering of metal, under the heads of electric welding, aluminothermy, soldering with water gas, with oxyhydrogen gas, and with oxyacetylene gas. Among the methods briefly discussed, with diagrams, are those of Bernardos, Elihu Thomson, Zérener, Goldschmidt's thermite process, based on the heat developed by the reaction of aluminium on metallic oxides, Strong, Lowe, Loomis, and Dellwik-Fleischer's water-gas processes, Garutti's oxyhydrogen process, and, at greater length, the Universal Acetylene Company's acetylene process, with the formulae and details on which it depends.

**High Speed Tool Steels.**—The report has been published ‡‡ of the tests with rapid-cutting steel tools carried out by a joint com-

\* *Journal of the Society of Arts*, vol. lii. pp. 256-268.

† *Engineering Magazine*, vol. xxvi. pp. 561-568.

‡ *Journal of the Franklin Institute*, vol. clvii. pp. 241-254.

§ Paper read before the Louisiana Engineering Society; *Iron Trade Review*, October 8, 1903, pp. 54-55.

|| *Engineer*, vol. xcvii. p. 169.

¶ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvi. pp. 1540-1541.

\*\* *Centralblatt der Walzwerke*, February 5, 1904.

†† *Bulletin Technologique de la Société des anciens élèves des Ecoles Nationales d'Arts et Métiers*, 1903, pp. 1341-1352.

‡‡ "Report on experiments with rapid-cutting steel tools." Read on October 21, 1903. Discussed on November 7, 1903. Manchester, 1904. Price 2s. 6d.

mittee of the Manchester Association of Engineers and the engineering sub-committee of the Manchester School of Technology. It covers 140 pages and is illustrated by 17 folding plates. In a paper read before the Coventry Engineering Society by J. M. Gledhill,\* of Sir W. G. Armstrong, Whitworth & Co., the subject was still further developed, and many examples were brought forward to show the advantages obtainable by the use of such steels. The first part of the paper was devoted to their manufacture and treatment, and the latter part to a discussion of results they had yielded. One of the points insisted on by the author was the necessity of providing ample driving power if the full benefit of the tools was to be realised. In illustration he mentioned that his firm, by employing a more powerful lathe, had been able to increase the speed of cutting armour-plate bolts, with a cut  $\frac{3}{4}$ -inch deep into the bolt, from 135 feet to 152 feet per minute, the tool, of "A.W." steel, still lasting seven or eight hours without requiring to be reground. Formerly it was considered fair work with ordinary self-hardening steel to cut eight such bolts in a working day of ten hours; now forty were produced in that time. The author referred to many other instances of improved performance obtained by the aid of these steels in other operations, such as milling, drilling, and machining hard materials like chrome steel, his results being taken not merely from the practice of his own firm, but also from that of various others, whose actual reports were quoted as an appendix to the paper. The author, in conclusion, emphasised the national importance of high-speed cutting, together with the employment of the most modern and efficient machine tools, if this country was to maintain its position in the engineering world and hold its own against competition. As to high-speed steel, we were only in the early stages of its manufacture and use, and when the steel-maker looked at the innumerable alloys of steel, the properties of which had still to be investigated, he could easily see what a large field of research had yet to be traversed.

C. Pendlebury † gives some notes on tests of rapid-cutting steel tools.

Rushmer ‡ has published a paper on the properties and manufacture of high-speed tool steel. The processes of hardening and tempering receive special attention.

\* *Times*, March 16, 1904.

† *Engineer*, vol. xcvi. pp. 331-332.

‡ *American Machinist*, vol. xxvii. pp. 1270-1271; *Iron Trade Review*, September 24 1903, pp. 50-51.



F. Holz \* discusses the speed and power used for milling and other tools.

Further tests made in America on rapid cutting tool steels have been published. †

G. Kuwadi ‡ reports on the trials made with various kinds of high-speed tool steel at the Japanese Imperial Arsenal, Osaka, with special reference to the power absorbed in driving.

**The Manufacture of Eye-Bars.**—W. R. Webster § gives some notes on the manufacture of 18-inch steel eye-bars. In making thin bars, difficulties were encountered from buckling when upsetting the ends and from defective heads in thicker bars. The latter is due to too high a rolling temperature. The question of testing is discussed especially in reference to annealing.

P. S. Hildreth || describes the method of making large eye-bars for the Thebes cantilever bridge over the Mississippi. The steel is made in the basic open-hearth from half pig and half scrap. Analysis showed 0.28 carbon, 0.45 to 0.55 manganese, 0.01 to 0.25 phosphorus, and 0.02 to 0.03 sulphur. The ultimate strength was 64,000 to 68,000 lbs., elongation over 25 per cent. and contraction over 46 per cent. The metal was cast into 5500 lb. ingots, 30 inches square, soaked in pits for six hours, bloomed down to 16 inches square, cropped, reheated and rolled in a 42-inch universal mill. The largest bars were 14 by 2½ inches in section, and 3 to 6 feet were cropped off each end. The ends were upset hot in three and sometimes in two operations in a hydraulic press, rolled, dressed, and punched. For annealing the bars were heated in batches in an oil-fired furnace to about 1400° F. in seven hours, allowed to cool to 650° or 700°, and then cooled in the air.

**Rails.**—W. Pestell ¶ describes recent progress in the process of electrically welding rail joints. In America about 208 miles of line have welded joints. Joints are now made with fishplates welded to the web at their centres and ends.

\* Paper read before the Cincinnati Metal Trades Association; *Iron Trade Review*, October 8, 1903, pp. 51-53.

† *Iron Age*, December 31, 1903, pp. 16-19.

‡ *American Machinist*, vol. xxvi. pp. 1250-1251.

§ *Engineering News*, vol. 1. p. 325.

|| *Ibid.*, pp. 326-327.

¶ Paper read before the American Street Railway Association; *Engineering News*, vol. 1. pp. 239-240.

The plant for electrically welding the rail joints on the Glasgow tramways and the results obtained are described by B. Taylor.\*

J. M. Swank† gives a historical account of the development of the manufacture of iron and steel rails in western Pennsylvania from 1830 up to the present day.

**Chilled Wheels.**—The manufacture of waggon wheels of chilled iron is briefly dealt with, some statistics being also given. It is pointed out that care has to be taken that there is a gradual transition from the hard chilled surface to the soft backing. If there is too distinct a line of demarcation the chilled portion will fly off when the wheel is in use.‡

**Steel Waggon.**—Painting and maintenance of steel railway waggon is dealt with in two papers by J. D. Wright§ and W. O. Quest.

**Structural Ironwork.**—Quoting from American newspapers, W. Linse|| describes the excellent way in which the steel structural portions of the "sky-scraper" and other buildings withstood the action of the heat at the great Baltimore fire. Illustrations are given which make this very evident.

An account,¶ with numerous illustrations of the buildings after the fire, has been given. The efficiency of the ironwork, as a protection against fire, is very marked.

Calculations are given by Weiske\*\* of the comparative strength of armoured and unarmoured concrete.

Ferrocement steel concrete for fire-proof buildings is described.††

**Construction of Cranes in Germany.**—H. Rupprecht‡‡ deals with the rise and progress in Germany of the crane construction industry. This industry, he points out, is of extremely ancient date,

\* *Engineering Review*, vol. x. pp. 119-126.

† *Pennsylvania Magazine of History and Biography*, January 1904; *Iron Trade Review*, January 14, 1904, pp. 47-50; *Iron Age*, January 21, 1904, pp. 12-13.

‡ *Stahl und Eisen*, vol. xxiii. p. 1247.

§ Papers read before the Master Car and Locomotive Painters' Association; *Engineering News*, vol. l. p. 315.

|| *Stahl und Eisen*, vol. xxiv. pp. 381-387, with eight illustrations.

¶ *Iron Age*, February 25, 1904, pp. 1-24.

\*\* *Dingler's Polytechnisches Journal*, 1903, pp. 795-799.

†† *Iron Age*, November 26, 1903, pp. 16-18.

‡‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 703-707.

and though in the lapse of ages gradual developments were introduced, it was not until first the use of the steam engine rendered further progress possible, and then the invention of the hydraulic crane by Armstrong in 1857, that any really important developments were made. From this period on the author traces the progress that has been made in this manufacture in Germany, dealing especially in this connection with the use of electric power.

**Manufacture of Projectiles.** — G. Kuwadi \* has published a description of the hydraulic plant for forging and drawing the steel shells of projectiles at the Imperial Arsenal at Osaka, in Japan. The presses are illustrated, and the process of manufacture is described.

**Manufacture of Tin-Plates.** — The manufacture of tin-plates is described by L. Dombrowski. †

\* *Engineering Record*, 1903, pp. 664-665.

† *Bányászati és Kohászati Lapok*, vol. xxxvi. pp. 714-749.

## PHYSICAL PROPERTIES.

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**Crystallisation of Iron.**—C. Benedicks \* has measured the angles of some fragments of cast iron which were taken from the base of a blast-furnace and appeared to show a crystalline structure. The measurements showed, however, that the fragments were not crystals but simply fragments fractured along planes of graphite, thus upholding the contention of H. M. Howe.†

**Surface Structure of Solids.**—The Hurter Memorial Lecture delivered before the Society of Chemical Industry on November 15, 1903, by G. T. Beilby, ‡ on the surface structure of solids has been published in book form.

**The Semi-Fluid State of Metals.**—According to T. Turner,§ at temperatures which more nearly approached the melting point the semi-solid condition became gradually more and more manifest, and every one was familiar with the fact, that red-hot metal could be readily squeezed into any desired shape. In such processes the metal was made to actually flow just like lead did at atmospheric temperatures. The temperature of annealing was merely that at which the material was sufficiently semi-solid to allow of free internal motion of translation, so that the particles might readjust their positions and thus remove any condition of strain. There was no sharp and clearly defined point at which a metal, in passing from the fluid condition, assumed all the characteristics of a typical solid. On the other hand, a solid, when near the melting point, retained or exhibited many of the properties of a liquid, including that of a considerable internal motion of translation

\* *Iron and Steel Metallurgist*, vol. vii. pp. 252-257.

† *Journal of the Iron and Steel Institute*, 1903, No. I. p. 707.

‡ Glasgow, 1903, with eight plates.

§ Paper read before the Staffordshire Iron and Steel Institute; *Iron and Coal Trades Review*, vol. lxxviii. p. 313.

within its mass. It was only at temperatures relatively remote from their points of fusion, that metals exhibited what were usually regarded as the characteristic properties of a typical solid. It was necessary to distinguish segregation, or an actual separation in bulk, in which one part of the mass was solid, and another part liquid, from the true semi-solid, which was, so far as ordinary chemical analysis was concerned, of uniform composition throughout. The cementation processes must be regarded as an example of molecular inter-penetration at a temperature considerably below the melting point of wrought iron, for such penetration naturally became less marked as the temperature decreased. It was well known that slow cooling led to the separation of carbon in the graphitic state, with the consequent production of soft grey iron, while rapid cooling gave combined carbon and hard white iron. It had been very generally assumed, though perhaps not very definitely stated, that the separation of graphite occurred at the moment of solidification, and that when the metal was once solid no further changes could take place. Recent observations had, however, completely changed the views of metallurgists on this subject. His own views on the separation of graphite were, that at the moment of solidification graphite separated chiefly in flakes or scales, which gave openness of grain and softness of texture. At lower temperatures carbon separated, chiefly as finely divided, or temper graphite, which gave softness combined with closeness of texture and strength.

**The Elastic Limit.**—W. C. Popplewell\* discusses the use of the term elastic limit in metals under stress, and shows that commercially it is regarded as the yield point and not the limit of proportionality. The meaning of these points, and the effect on them caused by variations in the manner of loading, &c., are discussed.

C. Frémont† defines the terms, theoretical limit of elasticity, and apparent limit of elasticity, and reports the results of tensile and compression tests carried out for the purpose of determining the elastic limit of different metals. The changes occurring in the metal when the limit of elasticity is reached are the subject of special observation. Illustrations of the arrangements for testing are given.

G. Dillner‡ considers the theoretical development of Brinell's ball-testing method. He determines the hardness and yield point by testing

\* *Engineering Review*, vol. x. pp. 299–307.

† *Bulletin de la Société de l'Encouragement*, vol. cv. pp. 350–377.

‡ *Jernkontorets Annaler*, vol. lviii. pp. 384–493.

with the ball under constant pressure, and studies first the effect of the chemical composition of the material upon the results obtained; secondly, the effect of treatment upon the results. Thirdly, he investigates the limit of elasticity by Brinell's method, and by a modification of it, and finally summarises his results.

H. Bouasse \* concludes, as the result of certain experiments: (1) A given deformation corresponds with a definite change of state which varies with the stress producing it. (2) This change is not, therefore, a function of the algebraic sum of the deformations. (3) A metal which has acquired a permanent set does not remain isotropic. (4) The change (hammer hardening) is a direct characteristic which cannot be expressed by a single number for each stage undergone. (5) Clapeyron, Saint-Venant, and Coulomb's theories are not, in their original form, held good for metal that has been worked, and in practice are inapplicable. (6) There is no scientific limit of elasticity, and rupture has but secondary importance.

**Metallography.**—F. Osmond, † C. Frémont, and G. Cartaud have endeavoured to group and classify the modes of distortion in iron and soft steels. Iron is to be regarded as an aggregate of equiaxial polyhedral grains somewhat similar to the cells of an organised body. Each cell is filled with a crystal of iron, crystallised in the cubic system. When the structural elements have no influence on the deformation due to distortion the iron may in some respects be regarded as amorphous. It must be admitted that iron possesses the three coexistent types of structure—amorphous, cellular, and crystalline. Each of these types may show distortion peculiar to itself. In the amorphous state, distortion follows geometric laws common to all bodies. When a definite structure is present, then common deformations are modified but are equally specific. In iron the authors distinguish the following types of deformation. (A) Common deformations applicable to the cellular structure, this group being subdivided as follows: (1) Microscopic foldings perpendicular or parallel to the direction of the stress. As the distortion proceeds they are replaced in the interior of the mass by the fringes which, as noted by Heyn, appear alternately dark or bright under an equal incidence of light. (2) Oblique foldings visible to the naked eye and known as "Lüder's lines"; under the microscope these lines appear

\* *Mémoires de la Société des Ingénieurs Civils de France*, vol. lvi. p. 589.

† *Génie Civil*, vol. xlv. p. 76; see also paper by W. Rosenhain in this volume of the Journal.

to be of the same nature as the fringes. (B) Purely cellular deformations, which group is further divided into two classes. (C) Purely crystalline deformations. This group contains three classes, the chief of which is deformation along cleavage planes. Iron of a cellular structure is very plastic, while iron having a crystalline structure is fragile, and as these two types of structure are superposed in the same specimen they apparently give contradictory results. It is this duality which gives to iron its particular position among materials of construction. This quality may also explain the unforeseen fractures which sometimes occur with the metal when in service.

F. Osmond, C. Frémont, and G. Cartaud \* contribute and inquire into the rationale of deformation of ferrite, and give an exhaustive series of photomicrographs of the structure of soft steels and iron undergoing stresses, and at breaking points.

J. E. Howard,† in some notes on the microstructure of steel, takes a very pessimistic view, and concludes that metallography is not in that state in which the microscope may be implicitly used for the accurate determination or recognition of those physical properties in iron and steel which give strength and safety to engineering structures. In the course of these notes, the author considers the microscope does not adequately indicate internal strains, while in the case of fractures, the cracks seem to pass indifferently through and around the grains.

A. Sauveur ‡ and H. C. Boynton illustrate by photomicrographs the influence of the rate of cooling on the structure of steel with the aid of two samples of 0.52 carbon steel, cooled from 1100° C., one in air and the other more slowly in the furnace. The first has a network structure and the slowly cooled material a granular structure, with true pearlite as the dark constituent. In the air-cooled sample, the dark constituent contains more ferrite which had not time to segregate. Thus to form pearlite the metal must be cooled slowly to a temperature below the critical point, the further rate of cooling being immaterial. The dilute or ferrous pearlite resembles Osmond's sorbite, which, however, is produced by relatively rapid cooling while the metal is passing through the critical range, so that the production of true pearlite is not fully completed. It is produced by rapid cooling from above the critical point if the speed is maintained through the critical range. The authors then offer several matters for discussion and investigation,

\* *Revue de Métallurgie*, vol. i. pp. 11-45.

† *Iron Age*, October 29, 1903, pp. 12-14.

‡ *Transactions of the American Institute of Mining Engineers*, February 1903.

such as the difference between sorbite and pearlite, the condition of the carbon in the sorbite, and the determination of carbon percentages by the appearance of the dark constituent.

In a paper on the physical structures of metals and alloys, J. J. Kessler, jun.,\* refers to the value of the microscope in ascertaining the most desirable annealing condition for steel castings and for sheet steel containing 0·07 per cent. of carbon used for electric appliances.

The subject of metallography is dealt with in a general manner by E. A. Schott. †

**Magnetic Properties of Iron.**—An arrangement has been devised by R. Richter ‡ for testing the magnetic properties of whole sheets so as to avoid cutting test-pieces. Illustrations are given.

The proposals of a commission appointed by the *Verband deutscher Elektrotechniker* to consider the question of hysteresis in iron and its determination are briefly summarised. §

J. A. Capp || discusses the electric conductivity of electric conductor rails and gives the analysis, resistance, and conductivity of forty-five samples. Manganese preponderates in influencing the resistance and should therefore be as low as possible. For a resistance equal to eight times that of copper the contents should not exceed :—

C.	Mn.	P.	S.	Si.
0·15	0·30	0·06	0·06	0·05

This metal can be made in the open-hearth and can easily be rolled.

C. Maurain ¶ shows the magnetic properties of iron carbides to be closely allied to the structure, and to the changes they undergo on heat treatment. He also incidentally discusses allotropic forms of iron, and questions of segregation.

C. Belloc \*\* reviews the methods adopted for examining the magnetic properties of iron and steel at different temperatures.

L. Fraichet †† has investigated the sudden variations in the reluctance of a magnetised steel bar submitted to tension as related to Lüder's lines.

\* *Journal of the Association of Engineering Societies*, December 1903.

† *Glückauf*, vol. xl. p. 36.

‡ *Engineering*, vol. lxxvii. pp. 145-146.

§ *Stahl und Eisen*, vol. xxiii. p. 1055.

|| *Transactions of the American Institute of Mining Engineers*, October 1903.

¶ *L'Eclairage électrique*, September 10, 1903; *Génie Civil*, vol. xlv. p. 16.

\*\* *Annales de Chimie et de Physique*, vol. xxx. pp. 42-98.

†† *Comptes Rendus*, vol. cxxxviii. pp. 355-356.



**Segregation in Steel.**—J. E. Stead \* considers the segregatory and migratory habit of solids in alloys and in steel below the critical points, and comes to the conclusions that near but below the eutectic point of the iron-phosphorus eutectic the two constituents, when quite solid, are capable of migration; that large crystalline masses attract the smaller particles; that there is no segregation when the whole mass is of eutectic composition; that active secondary segregation occurs when the eutectic is surrounded by masses of one of the constituents; that in the secondary eutectic pearlite, at temperatures below the eutectic point, there is the same tendency to migrate and segregate; and that heating steel at temperatures of 690° to 670° C. most rapidly produces a softening effect, and that in practical annealing, when the steel is slowly passing through the zone, the main softening effect is produced. It is, however, the zone in which the elastic limit is most rapidly reduced.

The same author † also reproduces a photograph of a metal containing about 2 per cent. of phosphorus and 97.8 of iron showing isolated patches of portions which first solidified.

**Determination of Critical Points.**—E. Saladin ‡ describes a new autographic method for ascertaining the critical points of steel. It is a modification of Roberts-Austen's arrangement to eliminate the variable time factor, and it consists in a means for deflecting the beam of light in two directions at right angles to each other by an inverting prism and lens with conjugate foci on the mirrors of the galvanometer. The curve traced on the screen has temperature and difference of temperature as abscissæ and ordinates. A series of curves, obtained in this way, are given for different varieties of carbon, nickel, manganese, titanium, and other steels.

M. Aliamet § sums up the theories of the allotropic transformations of iron, and the technology of the metallography of steel. He enumerates and defines the states  $\gamma$ ,  $\beta$ , and  $\alpha$ , and the critical points  $Ar_3$ ,  $Ar_2$ ,  $Ar_1$ ,  $Ac_3$ ,  $Ac_2$ ,  $Ac_1$ . Another state  $\delta$ , stable at 1300°, is, he considers, almost certain, and another, stable between 650° C. and 740° C., is also postulated.

\* *Journal of the Society of Chemical Industry*, vol. xxii. pp. 340-346; *Iron and Steel Metallurgist*, vol. vii. pp. 139-159.

† *Iron and Steel Metallurgist*, vol. vii. pp. 258-259.

‡ *Ibid.*, pp. 237-252.

§ *L'Electricien*, July 25, and August 29, 1903, pp. 49-53.

O. Boudouard \* describes his new method of determining the critical points of irons and steels.

**Heat Treatment of Steel.**—The sixth report of the Alloys Research Committee of the Institution of Mechanical Engineers, commenced by the late Sir William Roberts-Austen, but completed by W. Gowland, forms a paper of eighty-four pages, supplemented by thirty-nine plates of curves and photomicrographic reproductions. The object of the experimental work was mainly to observe and record the change in properties which different varieties of steel undergo when submitted to thermal treatment. The particular variety of steel selected was made at Sheffield, and was very pure. In no case does the manganese exceed 0.25 per cent., and it is generally less than 0.20 per cent. The steel, as received, was in the form of  $\frac{3}{4}$ -inch rolled bars, and was turned up into test-pieces. Of these eight series were employed, containing, according to F. W. Harbord, the following percentages of carbon :—

0.130   0.180   0.254   0.468   0.722   0.871   0.947   1.306

Tests were made on the different sets of bars as received, and after they had been subjected, respectively, to the following treatment :—

1. As received.
2. Annealed for half-an-hour at the following temperatures : 620° C., 720° C., 800° C., 900° C., 1100° C. The bars were packed in lime in  $\frac{3}{4}$ -inch wrought-iron tubes, closed at each end by screwed iron caps. These tubes were then packed in a large wrought-iron tube, the ends of which were covered with wrought-iron plates. This was placed in a closed gas-muffle, and a record of the temperature was taken by means of two thermo-couples attached to an autographic recorder.
3. Soaked for twelve hours at approximately the temperatures given in 2. The bars were packed in iron tubes in the same manner.
4. Quenched at the following temperatures in water : 720° C., 800° C., 900° C., 1200° C.
5. Quenched in oil. In these experiments the bars were subjected to the following treatment :—

- (a) Quenched at 720° C., and not reheated.
- (b) Quenched at 720° C., 870° C., and 1000° C., and reheated to 350° C.
- (c) Quenched at 800° C. and 900° C., and reheated to 600° C.

Each test-piece, after receiving its thermal treatment, had a portion of one of its ends removed for examination under the microscope. The

\* *Comptes Rendus*, vol. cxxxvii. pp. 1054-1056.

bars were then mechanically tested for : (1) Breaking stress ; (2) elastic limit ; (3) elongation ; and (4) reduction of area.

The remainder of the paper is devoted to a description of the results obtained from these different kinds of treatment.

From the results of annealing at 620° C., it would seem that both the elongation and reduction of area in worked bars are increased by annealing even at these low temperatures, but both these factors are increased to a still greater degree by heating to 720° C. for half an hour. On the other hand, the breaking stress of all classes of steel is considerably reduced by the latter treatment. With a temperature of 800° C., the 0·7 and 0·87 carbon bars are made much stronger as regards their breaking stresses, and their elongation and reduction of area are reduced to a minimum. A further increase to 900° C. does not materially alter the breaking stresses in the bars containing up to 0·871 per cent. of carbon. Beyond this point, however, it has increased the strength of the steel considerably, the 0·947 and the 1·306 bars having respectively a breaking stress of 11 and 5·4 tons greater than the same bars annealed at 800° C. The behaviour is similar in the cases of soaking for twelve hours at 800° C. and 900° C. The 0·871 per cent. carbon bar has no longer the greatest breaking stress of the series, that containing 0·947 per cent. of carbon being slightly stronger. The elongation and reduction of area are also practically the same as in the 800° C. annealing in all the bars up to and including that containing 0·871 per cent. carbon ; but the 0·947 and the 1·306 bars show a considerable reduction in these properties, the reduction being most marked in the latter, where extension has fallen from 20 to 5·5 per cent., and the contraction of area from 3·39 to 5·58 per cent. Annealing for half an hour at the uppermost limit of 1100° C. did not produce very marked divergencies from the results at 900° C., especially with the milder steels, but the three hardest steels showed symptoms in their micro-structure of being burnt.

Similar details are given for the soaking and hardening experiments, and the photomicrographs are fully described. The tensile tests are summarised in a number of tables.

**The Effect of Repeated Heating on Iron and Steel.**—A. E. Outerbridge, jun.\* has published the results of a number of remarkable experiments on the effect of repeatedly heating and cooling cast iron,

\* *Transactions of the American Institute of Mining Engineers*, February 1904; *Journal of the Franklin Institute*, vol. clvii. pp. 121-140, 311-314.

wrought iron, and steel. Cast-iron articles increase in size under this treatment, while steel, on the other hand, shrinks. One cast-iron bar, 1 inch square and 14.8 inches in length, after heating in a fire twenty-three times, grew 1 inch in length, and  $\frac{1}{16}$  inch transversely. When heated thirty-five times, the bar was 1.374 inch longer than its original size. This property has received a practical application to enlarging worn small cast-iron pistons used in type-casting machines. Steel and wrought iron shrink under this treatment. Low silicon iron cast into bars between end chills, when subjected to repeated reheatings, showed cup-shaped ends.

**Hardening of Steel.**—W. Metcalfe \* supports H. Field by quoting his own results and those of J. W. Langley, to show that hardening of steel depends on the tension in the metal, the first requisite being complete solution and not combination of the carbon. Increase of hardness accompanies decrease in density after cold rolling.

**Brittleness of Steel.**—H. Le Chatelier † defines the conditions relating to the nature of the metal, and to the external conditions upon which depend the brittleness. Chemical composition and chemical constitution are first considered, and then the structure of the metal as affected by casting temperature, hot working, heat treatment, and cold working. Of the external conditions, questions of impact, temperature, and shape are considered. Testing for brittleness is then dealt with, and the various methods proposed are briefly mentioned.

T. Turner ‡ describes Stead's recent experiments on the causes and prevention of brittleness in steel.

**Special Iron Alloys.**—R. A. Hadfield § reviews generally the subject of iron and steel alloys, and gives some new details of cobalt steel, and other alloys. The elastic limit, tensile strength, and percentage elongation are plotted for thirteen alloys containing as nearly as possible  $1\frac{1}{2}$  per cent. of each of the following elements: Carbon, silicon, aluminium, manganese, nickel, copper, chromium, tungsten, arsenic, phosphorus, and sulphur. The qualities of manganese steel are briefly described, and also those of steel containing most of the elements above referred to. The cobalt steels were made to contain 0.5, 2, 3, 6, and 9

\* *Transactions of the American Institute of Mining Engineers*, October 1903.

† *Iron and Steel Metallurgist*, vol. vii. pp. 125-134.

‡ Paper read before the British Association, 1903; *Engineering*, vol. lxxvi. p. 527.

§ *Iron and Steel Metallurgist*, vol. vii. pp. 3-21.

per cent. of cobalt. Tensile tests on annealed and unannealed bars are given, and show that cobalt has a similar effect to nickel in increasing the elastic limit and breaking load, besides which the action on the electric properties is similar. Then is given a comparison table of elastic limit, breaking load, elongation, reduction of area, and bending tests of forged silicon, aluminium, chromium, nickel, and tungsten-iron alloys, all the material having been annealed. These results are also plotted, and are followed by a tabular and plotted comparison of compression tests on forged unannealed silicon, aluminium, chromium, nickel, and tungsten-iron alloys. In conclusion, the author states that he has produced alloys with tensile strengths all the way from 18 tons up to 110 tons per square inch, and with elongations from nil to 70 per cent. But, singular as it may seem, notwithstanding the important part played by all these new iron alloys, carbon still maintains its premier position in determining the practical value of the various products, in other words, there are few, if any, iron alloys in which, apart from the effect produced by the special element added, the presence of carbon is also unnecessary, therefore, whatever the theory believed in, it has to be admitted that carbon alone is the predominant factor in determining the utility of the alloy. The writer does not state this in any controversial spirit, as, of course, the allotropist, whilst admitting the importance of carbon, claims that its action is different to that believed in by the carbonist, but the fact remains that carbon must be present to render the alloy of practical value.

According to J. Ohly,\* in the manufacture of chrome-nickel armour-plates use is made of a ferro-chrome nickel alloy containing—

Cr.	Ni.	Fe.	C.	Si.
74	24	2 to 2.5	0.75 to 1	0.25 to 0.5

These armour-plates, by simply tempering, show a surface hardness equal to that attained by Harveyising. Ferro-tungsten nickel, containing about 74 per cent. tungsten, 24 per cent. nickel, and 2 per cent. iron, is used where the simultaneous addition of accurate quantities of nickel and tungsten are required, but this type of alloy has not been widely adopted. Ferro-tungsten has been substituted for powdered tungsten in the manufacture of self-hardening steels. A normal type of ferro-tungsten is as follows:—

W.	Fe.	C.	Si.	P.	S.
83.82	10.90	3.20	1.87	0.10	0.11

Tungsten steels are usually manufactured by the crucible process,

\* *Mines and Minerals*, vol. xxiv. pp. 109-110, 211-212.

and contain 2 to 10 per cent. of tungsten, and 1 to 5 per cent. of carbon, according to the character of the steel required. The steels are exceedingly hard, and are chiefly made in the form of tool steels. As tungsten steel retains magnetism it is largely used for permanent magnets. A steel adopted for this purpose contains about 7·5 per cent. tungsten, otherwise being of normal composition. A remarkable and interesting compound is that known as "ferro-phosphorus," which is used for a special purpose. Where strength and toughness are not of prime moment, but the properties of cutting freely and taking a high polish are chiefly required, then a steel of fairly high phosphorus is specially suitable. Steel containing up to 1 per cent. phosphorus is suitable for use in automatic screw-making machines, the products having a very smooth surface, a fine and bright polish. Ferro-molybdenum is prepared by adding the requisite quantity of molten iron to a bath of fused molybdenum. The alloy is very pure and uniform, containing 50 to 85 per cent. of molybdenum. Molybdenum steels made by means of this alloy are claimed to possess properties superior to tungsten steel, and after quenching with water, the former is stated to be stronger and less brittle than the latter. The ferro-molybdenum alloy has been further improved by the introduction of various percentages of nickel, an alloy used to some extent in the manufacture of steels for forgings, guns, rifle-barrels, wire, boiler-plates, and shells. The alloy is added in such a quantity that the finished molybdenum nickel steel contains 0·25 per cent. of molybdenum. This amount increases the elongation from 4 to 45 per cent., and the steel is very suitable for the manufacture of plates for high pressure boilers, or boilers of torpedo boats.

**Manganese Steel.**—L. Guillet\* continues his account of experiments on special steels by a lengthy article on manganese steel. The object of the researches, which were commenced on nickel steels, is to investigate the mechanical properties of the steels and their critical points, and to determine their metallography. The steels were divided into two series, according to their carbon contents. The first series comprised steels of 0·05 to 0·3 per cent., and the second 0·7 to 1·0 per cent. of carbon. The steels were made by the Commentry-Fourchambault Company, at their works at Imphy. The first part deals with the metallography of these steels, and it is stated that with a manganese content varying from 0·0 to 4·2 per cent. the constitution of the first

\* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. cv. pp. 421-434.

series resembles that of ordinary carbon steels. With 5.65 to 12.7 per cent. of manganese they consist chiefly of martensite. Steels of the second series also resembled ordinary carbon steel, up to 3 per cent. of manganese. With 3.0 to 5.0 per cent. of manganese, a microstructure not previously observed revealed itself. In both the above series the material was unworked cast steel, reheated steels were next observed, and then hardened steel, and the researches were extended to the examination of hammered steel, specially cooled steel ( $-78^{\circ}$  to  $-180^{\circ}$ ), and cemented steel. The results were in all cases comparable; below a certain manganese content they resembled ordinary carbon steels, while above these limits they partook chiefly of the nature of martensite. The author next passes to the mechanical properties of the steels, and then gives the results\* of some exhaustive experiments carried out on a series of steels containing from 0.05 to 1.0 per cent. of carbon, and 0.4 to 33.5 per cent. of manganese. He finds that, as compared with ordinary steels containing the same amount of carbon, the addition of manganese greatly improves them. It is also found that manganese can replace the nickel in nickel steels, and that a much smaller proportion of manganese is capable, without making the steel unduly brittle, of conveying a degree of hardness equal to that due to a much higher proportion of nickel.

A. Ledebur† considers the investigation of L. Guillet as to the properties of manganese steel, referring in the first instance to the original publication on this matter by Hadfield in 1888. In this Hadfield showed that the hardness and brittleness of the metal increase at first, reaching a maximum with about 6 or 7 per cent. of manganese. The brittleness then begins to diminish, again reaching a minimum when the manganese is between 10 and 12 per cent., and then again increases, the metal with 10 to 12 per cent. of manganese also becoming tougher instead of harder when plunged from a high temperature into water. Mukai subsequently confirmed these observations, and the investigations have since been further taken up and elaborated by Guillet, who also extended them to manganiferous ingot iron low in carbon. Guillet's results are given by the author in detail; they confirmed Hadfield's original investigations. The reduction in brittleness and in hardness on "hardening" became noticeable with 7 per cent. of manganese for steel containing much carbon, and for steel low in carbon at 20 per cent. of manganese.

\* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. cv. pp. 435-448.

† *Stahl und Eisen*, vol. xxiv. pp. 281-285.

**Nickel Steel.**—A. L. Colby \* discusses the use of nickel steel for boiler tubes. Until recently they were mostly made in France, by the Ehrhardt process, and some were made in Germany by a cupping process. Recently they have been made in America as cold-drawn tubes from 30 per cent. nickel steel with very successful results. The saving in weight and extra cost for marine boilers is considered. Tests show considerable advantages under boiler conditions as regards corrosion and alternating expansion and contraction. Other uses of these tubes are also dealt with.

A. L. Colby † has published an elaborate comparison of certain physical properties of nickel steel and carbon steel, proving the superiority of the former for bridge and structural purposes. The volume, which covers 103 pages, contains a full bibliography of the subject.

The properties of magnetic and non-magnetic nickel steels are dealt with by L. Dumas. ‡

O. Boudouard § investigates the allotropic transformations of certain specimens of nickel steels containing 2 per cent. and 30 per cent. of nickel, by means of curves obtained during the heating and cooling of bars of the metal.

The physical properties and uses of nickel steel are summarised by W. H. Warren. ||

**Silicon Steel.**—L. Guillet ¶ investigates the characters of silicon steels, ranging them into two types—containing 0.55 to 0.65 per cent. of carbon, and 1.2 to 1.3 per cent. of silicon, and 0.65 to 0.7 per cent. of carbon, and 0.8 to 0.9 per cent. of silicon respectively. He gives their micrography, and the results of numerous tests, his paper being copiously illustrated with photomicrographs and diagrams.

**Vanadium Steel.**—L. Guillet \*\* distinguishes three distinct groups of vanadium steels, one being intermediate in properties between the other two. He also describes the mechanical properties of each of the groups, and shows that the steels of each present very remarkable

\* Paper read before the Society of Naval Architects and Marine Engineers, New York; *Iron Age*, November 26, 1903, pp. 10-12.

† *Nickel Steel and Carbon Steel*, 4to, 104 pages, New York, 1903.

‡ *Bulletin de la Société de l'Industrie Minière*, vol. ii. pp. 641-688.

§ *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences*, vol. cxxxviii. No. 6, pp. 370-371.

|| *Report of the Ninth Meeting of the Australasian Association for the Advancement of Science*, Hobart 1902, pp. 685-716.

¶ *Comptes Rendus*, vol. cxxxvii. pp. 1052-1054.

\*\* *Ibid.*, vol. cxxxviii. pp. 367-369.



characteristics. Lastly, he determines the fact that only vanadium steels containing less than 7 per cent. of vanadium are suitable for industrial use, on account of the brittleness of those containing larger percentages of vanadium.

**Faulty Boiler Plates.**—H. Otto\* refers to the occurrence of cracks in boilers. The author, on behalf of the International Verband der Dampfkessel-Überwachungsvereine of Stockholm, has investigated the question as to what variations in tenacity and elongation are permissible in one and the same plate for uniform material. Reference is made to the views that have been expressed by other writers on these points. Weld-iron plates, now, however, rarely used in boiler construction, if tested in different parts, give varying results. This variation cannot therefore be held to be solely shown by plates made of ingot metal. The author gives a series of results of tests made right across a plate made of weld iron 0·59 inch in thickness. There were 21 such test pieces cut out, No. 1 being at one side of the plate and No. 2 at the other. The maximum tensile strength was that shown by No. 9, near the middle of the plate. Here the tensile strength was as much as 24·06 tons per square inch, while from this maximum, with slight variations, it fell to 21·97 tons at one edge and to 21·08 tons at the other side. A number of other tests which the author made showed similar variations. The author concludes that in any such plate a variation in the tensile strength of test-pieces taken from it may amount to about 2·86 tons in the maximum tensile strength and to 7 per cent. in the elongation, but this includes errors in testing. Similar figures are given for ingot iron plates. Again the maximum strength lies towards the middle of the plate, but the variations are very much less than in the case of weld iron. Samples taken across the fibre and along it showed much the same results both for tensile strength and for elongation. The foot of the plate was lower in tensile strength and higher in elongation than the head. The variations in this plate amounted to a maximum 2·35 tons in tensile strength and 5·5 per cent. in elongation along the fibre, and to 2·22 tons and 5·5 per cent. across it. Drawing his deductions, however, from 2000 plates of all kinds of shapes and thicknesses, and with tensile strengths that varied between 22·22 and 28·57 tons, the author shows that 60 per cent. exhibited variations in tensile strength that amounted to 1·90 ton, 37 per cent. showed a difference of from 1·90 to 2·86 ton,

\* *Stahl und Eisen*, vol. xxiii. pp. 1369-1372, with two illustrations.

and 3 per cent. showed still greater differences. The variations in elongation reached as much as 9.5 per cent. It follows, therefore, that in plates of ingot metal the differences in tensile strength shown by any one plate are just as great as they are in the case of weld iron plates, but they are more uniform in their distribution in ingot metal plate. The variations in elongation are somewhat greater in the case of plates of ingot metal than they are in those of weld iron, attaining 10 per cent. for the former as compared with about 7 per cent. for the latter. The author's investigations were not confined solely to boiler plates, but included others used for other purposes, and these results are therefore of a general rather than a special character.

Künzel \* points out that a series of defects have again been recently observed in boilers made of ingot metal for which no explanation could be given, with the result that doubt might be thrown on the suitability of this material for boiler purposes. The author gives a list of 19 such cases in which cracks occurred in boiler plates. In 10 of these, explanations for such failures could be given or guessed. For the remainder there was no explanation apparent, and the author thinks that the material of which the plates was made must have been at fault, and that the existing mechanical tests are consequently inadequate. This paper was much discussed. The treatment to which the metal had been subjected in the boiler-making shop, Eichhoff thinks, may have much to do with these subsequent failures in practice.

At the instance of the Alsatian Association of Owners of Steam-boilers, a number of tests have been carried out for the purpose of investigating the actual condition of boiler plates which had been over 35 years in service, and the results were presented in the form of a note by Walther-Meunier.†

At the 27th Congress of the Associations of Steam-boiler Owners, held at Paris, a large number of test-pieces were cut from two old boilers, dating respectively from 1854 and 1859, and were tested for their tensile strength and bending capacity. The results are given in four tables, in which are noted the place from which the strips were taken, the tensile strength, the percentage of elongation, the angle at which rupture occurred during bending, the chemical composition, and the appearance of the fracture. In general, it was found that the metal forming the plates was lacking in homogeneity, and that consequently

\* *Stahl und Eisen*, vol. xxiv. pp. 51-52.

† *Compte Rendu des Séances du 27me Congrès des Associations de Propriétaires d'appareils à vapeur*, 1903, pp. 15-29.

the tensile strength was anything but uniform, the difference between various specimens exceeding even 28,500 lbs. per square inch in some instances. The elongation never attained 25 per cent., and in a great number of cases proved to be nil. The conclusion drawn is that plates which have been long in service are chiefly dangerous on account of their almost complete lack of elasticity and of homogeneity, which causes sudden rupture to ensue where otherwise only a slight deformation might occur.

**Testing-Machines.**—A 300 ton Buckton testing-machine \* has been completed for the new testing laboratory of the Conservatoire des Arts et Métiers, Paris. It will test up to 300 tons a column 88 feet long and 39 inches square in compression, or 8 feet less in length in tension. For transverse tests it will test beams up to  $6\frac{1}{2}$  feet deep by  $3\frac{1}{4}$  feet broad on centres 20 feet apart.

A. L. Monrad † describes various types of screw micrometer gauges for the measurements of thicknesses of metals.

Illustrations are published ‡ of a new form of German machine for the testing of cast iron. A special form of automatic registering appliance is attached. The machine is in use at the testing laboratory at the Technical High School at Aix-la-Chapelle, where it is stated to have given very satisfactory results.

**The Effect of Alternate Stresses.**—According to C. B. Dudley § the cause of fracture under alternating stresses is not altogether clear, but the three variables involved are the maximum fibre stress, the nature of the metal, and the number of applications of the stress. To resist such repeated stresses, stiffness rather than toughness is required, and three examples are quoted to show that a higher carbon steel has been used with success for railway axles, sugar-mill rolls, and steam-hammer piston rods which failed when made of a milder quality.

**Tensile and Repeated Stress.**—J. E. Howard || gives the following details of the action of tensile and repeated stresses on two kinds of steel :—

\* *Engineer*, vol. xcvii. p. 110.

† *American Machinist*, vol. xxvi. pp. 1524-1526.

‡ *Stahl und Eisen*, vol. xxiv. pp. 38-39, with four illustrations.

§ *Iron and Steel Metallurgist*, vol. vii. pp. 134-139.

|| *Iron Age*, October 29, 1903, pp. 12-14.

Carbon per Cent.	Elastic Limit. Lbs. per sq. in.	Tensile Strength. Lbs. per sq. in.	Elongation on 6 inches. Per Cent.	Contraction of Area. Per Cent.
0·17	48,000	71,360	24·2	49·7
1·09	70,000	132,320	9·7	15·0

Under repeated alternate stresses attaining 40,000 lbs. per square inch, a shaft of the 0·17 carbon steel ruptured at 366,500 repetitions, while the other steel endured 130,000,000 repetitions, and was subsequently fractured by application of a higher fibre stress. The mechanical work of the most strained fibres is given in foot-pounds as follows :—

Carbon per Cent.	Tensile Test.	Endurance Test.
0·17	1023	814,000
1·09	945	288,000,000

**The Physics of Cast Iron.**—W. R. Webster \* has given the following suggested lines for discussion and investigation :—

I. Correspondence between chemical composition and melting-point, fluidity, shrinkage, fracture, chill, microstructure, and other physical properties.

II. Influence of :

- |  |   |    |   |
|--|---|----|---|
| <ol style="list-style-type: none"> <li>1. Cupola-mixture, use of steel and other scrap, oxidised or clean material,</li> <li>2. Manner of melting, flux, &amp;c. .</li> <li>3. Casting temperature,</li> <li>4. Manner of handling melted metal and method of casting,</li> <li>5. Size and form of casting,</li> <li>6. Kind of mould, green sand (under different conditions of ramming, amount of moisture, and skin-dried), dry sand, loam, and chills,</li> <li>7. Rate and mode of cooling castings,</li> <li>8. Manner and temperature of heating for annealing,</li> <li>9. Additions of nickel or aluminium,</li> </ol> | } | on | <ol style="list-style-type: none"> <li>A. Fracture.</li> <li>B. Microstructure.</li> <li>C. Physical properties.</li> <li>D. Shrinkage.</li> <li>E. Chill.</li> <li>F. Residual stress.</li> <li>G. Condition and quantity of carbon and other elements.</li> </ol> |
|--|---|----|---|

III. Segregation as affected by : (1) Composition ; (2) casting temperature ; (3) rate of cooling ; (4) size and shape of casting.

IV. Blow-holes, their volume and position as affected by : (1) Composition ; (2) casting temperature ; (3) casting pressure ; (4) rate of cooling ; (5) size and shape of casting ; (6) special additions.

A bibliography of the discussion which has ensued on these lines is given, and the latest contribution is by R. Moldenke,† who reviews recent

\* *Transactions of the American Institute of Mining Engineers*, February 1904.

† *Ibid.*

work on the physics of cast iron, and deals with the following points: (1) Correspondence between chemical composition and melting-point, fluidity, shrinkage, fracture, chill, microstructure, and other physical properties; (2) cupola mixture, manner of melting in the foundry, casting temperature, size and form of casting, kind of mould, manner and temperature of annealing, additions of nickel and aluminium; (3) segregation; (4) blowholes. It is considered that future research should devise methods of controlling the chemical composition in blast-furnace and cupola, irrespective of the nature of the pig iron and scrap charged. Sulphur, phosphorus, and oxygen should be eliminated by these means.

**Testing Cast Iron.**—Further details are given relating to the paper by O. Leyde \* on the testing of cast iron. Relatively little has been done in connection with the testing of cast iron as compared with the attention that has been devoted to iron and steel. Cast iron is a material that crystallises on cooling down from the molten state. The transition from an apparently amorphous into a crystalline condition is often observable in the hollows met with in castings. If, during the formation of such crystals on slow cooling, graphite also crystallises out between the other crystals, it may happen that they will be entirely separated from each other. Coarsely crystallised cast iron is therefore weaker than is that which is of finer grain. The more slowly the metal cools the larger will be the size of the crystals produced, as the author shows, and with this increase in the size of the crystals there is a corresponding decrease in the strength of the casting. It is therefore possible to cast from the same ladle of metal a thick casting of but little strength, thinner castings of increasing strength, and finally a very thin one that will be white, hard, and brittle. The foundryman has to mix together for each of his castings a number of pig irons that will produce as fine a grain as is possible. With the other difficulties connected with the selection this author does not deal. Up to now the only standard size cast-iron test-pieces acknowledged have been those one metre in length and thirty millimetres square in cross section (39·34 inches by 1·18 inch by 1·18 inch). These are, however, only satisfactory for a very limited range of castings of approximately similar dimensions. In the author's opinion the test-pieces should be cast cylindrical in rising moulds at the ordinary casting temperature and should be allowed to cool in sand. Tensile tests are

\* Read before the Deutscher Verband für die Materialprüfungen der Technik.

of little value, as a test-piece will always break at the point where there is a flaw if one be present. Bending tests have the great advantage that they show the degree of elasticity of the cast iron, whereas the tensile tests do not. It is especially necessary to determine the resistance of cast iron to percussion, and with this the author deals. The determination of the hardness is also dealt with, drills which bore upwards being better for this purpose than are those which act in the opposite direction, as they are not so hindered in their action by the drillings. If two castings are of the same thickness, but of different degrees of hardness and strength, this points to varying chemical composition. This leads the author to consider the question of the chemical composition of foundry iron, and the way various elements present affect the mechanical properties of the metal.

P. Reusch \* deals with the question of the influence which the shape and method of preparation of cast-iron test-pieces exert on their mechanical properties when under test. The results of a number of experiments are given, and from these the author deduces the following conclusions: (1) The bars should be cast, in an undivided box, without any fins; (2) they should be cast from below; (3) a certain definite power of resistance to a bending force should be specified dependent on the cross-section of the rod, which in turn should bear some relation to that of the finished casting; and (4) the cross-section of the rods should be circular. The round rods gave far better results than those that are rectangular in cross-section.

A Committee of the American Society for Testing Materials has issued† some proposed specifications for malleable castings and for grey iron castings. For the former sulphur should not be over 0.06 nor phosphorus over 0.225. Cupola-melted metal should not be used, but it is understood that grey castings are made in that way. In them sulphur is restricted to 0.08, 0.10, and 0.12 per cent. for light, medium, and heavy castings respectively. The methods of casting the test-bars are specified in each case, and also the methods of testing.

R. Moldenke ‡ advocates the use of a test-bar  $1\frac{1}{4}$  inches square and 15 inches long for transverse tests of cast iron on supports 12 inches apart. The bar should be cast vertically, and the bottom of the mould should be rounded. The number of bars for each cast and a general specification for the method of testing is given.

\* *Stahl und Eisen*, vol. xxiii. pp. 1185-1191.

† *Iron Trade Review*, February 11, 1904, pp. 37-38.

‡ Paper read before the New England Foundrymen's Association; *Iron Age*, February 18, 1904, pp. 22-24.

**Strength and Structure of Cast Iron.**—O. Leyde \* deals with the question of the relations existing between the strength and the structure of cast iron. The mechanical tests, which cast iron is required by various users to withstand, differ very greatly, as the author shows. It is not, however, usually customary to require any special ways of casting and preparing the test-pieces. The strength shown by cast-iron test-pieces depends very largely on their dimensions, and among other points, whether they were cooled quickly or slowly. The various parts of a locomotive cylinder casting are exposed to varying cooling periods, according to their thickness. In this way they have more or less opportunity, as the case may be, for coarse crystallisation—for the separation of graphite—and they are consequently all of different degrees of strength. These are usually weaker than test-pieces cast at the same time, and from the same metal. The latter are usually of less dimensions, consequently cooling more quickly and possessing a finer grain. They can therefore only be considered with the greatest reserve, in connection with the probable strength of the cylinder parts. This the author shows by the results of a series of such comparative tests. These great variations led the author to suggest comparative test of bars of differing cross-sections. In all 12 bars were cast, varying from 0·4 inches square to 5·9 inches square in cross-section, the same metal being used for all of them. The metal contains about:—

Total Carbon.	Phosphorus.	Manganese.	Sulphur.
3·0	0·6	0·7	0·12

The pieces were fractured, and photographic records of their cross-sections are shown. The most desirable structure was shown by the specimens, which were respectively 1·6, 2·4, and 3·2 inches square in section. The bars of smaller section were mottled, and even almost white, and the structure of the thicker bars was too coarse. It is advisable to avoid altogether the standard dimensions hitherto customary, and to vary them according to the thickness of the metal in the casting under test. The author next deals with the bending test, which he considers very valuable. The bars referred to above were tested in this way, and the thinner ones, which had been more rapidly cooled, proved relatively very much stronger than the larger ones that had cooled more slowly. The percentage of graphite present rose gradually from 2·55 per cent. in the case of the bar of smallest section (No. 1), to 2·98 per cent. in that of No. 10 of the series, No. 11 being again a little

\* *Stahl und Eisen*, vol. xxiv. pp. 94–102, with twelve illustrations.

less—2·92 per cent. The author considers that it is not so much the actual percentage of the graphite that causes the change in the mechanical properties of the metal, as the position of the various particles.

F. Wüst\* and P. Goerens discuss the chemical composition and physical properties of the cast iron used for steam cylinders. A number of firms were asked to give test-pieces for the purpose of these experiments, which were made at the Technical High School at Aix-la-Chapelle. Twenty-one firms responded, each giving five test-pieces relating to one particular cast, and forty-six casts in all were dealt with. The test-pieces were all cast in a uniform manner in dried vertical rising moulds. The five moulds were each connected together at the bottoms with a central mould, into which the metal was charged. No covers to the moulds were employed. The test-pieces were each 21·7 inches long, and 1·18 inch in diameter. They were analysed and examined by the bending, tensile, and percussion tests. The chemical composition of the bars varied within the following limits:—

	Per Cent.
Silicon . . . . .	0·920 to 2·23
Manganese . . . . .	0·200 „ 1·27
Phosphorus . . . . .	0·120 „ 1·22
Sulphur . . . . .	0·054 „ 0·18
Total carbon . . . . .	3·200 „ 3·76
Combined carbon . . . . .	0·520 „ 1·46
Graphite . . . . .	2·060 „ 3·24

The samples containing the maximum percentages of each particular constituent above named had the following compositions:—

Maximum.	Si.	Mn.	P.	S.	Total C.	Comb. C.	Graphite.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silicon . . . . .	2·23	0·65	1·10	0·111	3·58	0·73	2·55
Manganese . . . . .	1·54	1·27	0·54	0·112	3·46	0·77	2·69
Phosphorus . . . . .	1·81	0·68	1·22	0·084	3·37	0·58	2·79
Sulphur . . . . .	1·15	0·77	0·93	0·180	3·47	1·11	2·36
Total carbon . . . . .	1·68	0·69	0·36	0·054	3·76	0·52	3·24
Combined carbon . . . . .	1·82	0·57	0·69	0·148	3·53	1·46	2·07
Graphite . . . . .	1·68	0·69	0·36	0·054	3·76	0·52	3·24

These percentages are given for every sample, and the results of the mechanical tests are also given in each case.

The absolute tensile strength varied from about 15,300 lbs. per

\* *Stahl und Eisen*, vol. xxiii. pp. 1072-1077, with six illustrations.



square inch to 35,200, and relative tensile strength from about 43,050 lbs. to 70,750. The bars bent from 6·07 to 10·54 millimetres before breaking. The absolute and relative tensile strengths are dependent on the percentages of silicon and total carbon that are present, the rule being, that when the silicon is high, the absolute tensile strength is at its maximum when the total carbon is at its lowest; and inversely the maximum is attained when the total carbon is high and the silicon is at its minimum percentage. The sulphur present has little or no influence on the absolute tensile strength, but it exerts much influence in connection with the bending properties of the metal. It is the relative strength that is affected, not the absolute. Phosphorus acts in a somewhat similar way, affecting the bending properties rather than the tensile strength. The material rich in phosphorus bends before fracture more than that which contains less of that element. Very high contents, above 0·90 per cent., of combined carbon have a similar action. The phosphorus shows far greater influence in connection with the percussion tests. Comparing all the tests, the author considers that the best results were given by the samples that contained the following percentages:—

Si.	Mn.	P.	S.	Total Carbon.	Combined Carbon.	Graphite.
0·92 to 2·13	0·56 to 1·21	0·23 to 0·99	0·06 to 0·12	3·36 to 3·62	0·63 to 0·87	2·53 to 2·66

**Tests of Metals.**—The report for 1902, on tests of metals at Watertown Arsenal, contains the usual voluminous series of all sorts of tests. Amongst others, there are records showing the improvements in the tensile strength of puddled iron by quenching in water and in oil, the improvement in nickel steel after forging, quenching, and annealing, the endurance of rotary shafts, &c.

Details are now given \* as to the tests carried out at the *Königliche technische Versuchsanstalten* in the year 1902.

L. Katona † draws attention to the incongruity of referring the maximum load to the original section of a test-bar, and the final elongation to the original length.

G. Charpy ‡ gives a critical review of the new method of testing by means of notched bars.

**Variations in Structure and Tests of Steel.**—A. Campion§ and H. W. Watts endeavour to show how far the variations in micro-

\* *Stahl und Eisen*, vol. xxiv. pp. 371–374.

† *Engineering*, vol. lxxvii. p. 339.

‡ *Baumaterialienkunde*, vol. viii. pp. 274, 289, 306, 322, 342, 357.

§ *Journal of the West of Scotland Iron and Steel Institute*, vol. xi. pp. 93–106.

structure, chemical analysis, and physical tests are likely to affect the indication of the properties of the whole mass as derived from a single specimen. For this purpose the results are given of microscopic investigation, analysis, and tensile tests on the ends of bars, rails, and other articles of various sizes and shapes. The structure of steel of small mass and regular shape discloses but little variation at different parts of the piece, provided it has been subjected to the same treatment throughout. Round bars of large diameter of rolled material, and forged material for axles and spindles, may exhibit considerable differences of structure between the outside and central portions. The differences, however, are (excepting in cases where the material has been specially treated) very little if any greater than those obtained in analytical and mechanical testing. Material in irregular shapes and unequal masses exhibit very considerable differences as regard both analyses and structures in the various portions of the section. Axles and tubes of guns, which have been subjected to special treatment, as oil quenching and tempering, show the effects of the treatment in a marked degree on the outside portions. The carbide areas gradually diminish in volume towards the centre where the structure (except in material of very small diameter) exhibits that of the material before treatment. Although a large number of etching media have been suggested by various operators, they all give identical results when used under suitable conditions. The structure of some steels may be much more clearly developed by one method than another; but the ultimate result, as far as size of grain and constituents present, is the same in all cases. The authors point out that samples for microscopic investigation must be taken in the same way and with the same care as samples for analysis, that is, with precautions to ensure a representative sample. For rails one sample from the running edge and one from the centre of the head will generally suffice, and their indications will often explain discrepancies in work.

**Tensile Tests of Mild Steel.**—In the case of steel, the engineer relied on tests of samples for assurance that he was obtaining suitable material. It was important, therefore, that the information given by tests should be definite and comparable. Mechanical tests were for the engineer the most important, but as usually conducted they were not wholly satisfactory, and had to be supplemented. The object of a paper by W. C. Unwin\* was to consider some conditions which affected the

\* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. clv. pp. 170-292, 411-413.

results of tests, especially as regarded the measurement of ductility. Ductility was probably the most important quality in the material for working purposes. Some conditions were then discussed. The time effect was only negligible provided inertia forces might be neglected. The method of gripping the test-bar and the form of fracture as affecting the results were discussed, and the influence of enlarged ends on the elongation. The effect of the position of fracture between the gauge points was examined, and some numerical results were given. Next the effect of small variations of cross section, which was greater than was ordinarily supposed, was shown. The total elongation was shown to consist of a general stretch, nearly uniform along the bar, and a local stretch. As geometrically similar bars deformed similarly, the percentage of ultimate elongation was the same in similar bars of the same material. An account was then given of a series of tests on ship and boiler plates of different thicknesses, made for the Engineering Standards Committee. The results were first discussed by using plotted curves without assuming the elongation equation. Taking from the curves the elongations for bars of a standard form, the real relative ductility of these bars was found. This was compared with the elongations for bars of constant width such as were generally used in testing. It was shown that the elongations in the latter case were very misleading as to the relative ductility. In the case of similar bars the ductility decreased as the thickness of the plates increased. But the results on bars of constant width would lead to the conclusion that the thickest plates were the most ductile. The constants in the elongation equation were then given for the bars in each of six series of tests and for plates of  $\frac{1}{4}$  to  $1\frac{1}{4}$  inch thick, with a detailed comparison of the elongations calculated by the equation and observed in the tests. A further series of tests on plates with varying percentages of carbon was given. The constants  $c$  and  $b$  in the elongation equation decreased as the percentage of carbon increased. Lastly, a series of tests was made by F. C. Fairholme, of the Cyclops Steelworks, on short test-bars cut from tires and axles. It was shown that the elongation equation was applicable to these short test-bars. The forms of short test-bars which could be used in such cases was discussed, and a very simple recommendation was made which would secure that in all such tests the elongations would be comparable. The question of quality figures for materials was then examined. It was pointed out that if quality figures were to be of value the tests must be made on similar test-bars, or the results must be reduced to equivalent results on similar bars. The values were ex-

amined of the quality figure for the whole of the tests described in the paper for test-bars of different areas of section.

The Engineering Standards Committee has issued a report\* dealing with the variation of elongation with different gauge lengths and sections of test-bar. It is based upon tests of steel plate test-bars from the Dalzell Steelworks and the Park-gate Steelworks. The tests cover a wide range of conditions, and no such complete information as to variation of elongation with the form of test-bar has been previously available. As standards, W. C. Unwin suggests that for plates the gauge length should be 8 inches and the cross section of the bar less than 1 square inch for plates from  $\frac{3}{8}$  to  $\frac{7}{8}$  inch in thickness, or the width of the bar not more than 2 inches. For plates of less than  $\frac{3}{8}$  inch thick it would be better to make the greatest width  $2\frac{1}{2}$  inches, and for plates more than  $\frac{7}{8}$  inch thick, to make the greatest width  $1\frac{1}{2}$  inch.

Schmitz † has investigated the mechanical properties of iron and steel bars, with special reference to the influence of the form of section of the test-pieces, of the rate of application of the load, and of the duration of stress due to loading.

### Strength of Steel Castings as Affected by Temperature.—

Experiments have been made by C. Bach ‡ to determine the relation of mechanical strength of steel castings to temperature. It is shown that the average tensile strengths increases up to about 300° C., time of loading not having any appreciable influence. For higher temperatures, on the other hand, the mean tensile strengths are found to decrease when loads are applied for half-an-hour, and still more when the loading endures for eight to twelve hours. The results of some of these tests are given, showing a marked decrease. The average breaking strengths are found to decrease very considerably in some cases with a temperature range of 20° to 200° C., but above that point the average breaking strength increases again up to 500° C. Prolonged loads result in the strength being lowered at 300° C. and 400° C., and augmented at the temperature of 500° C. The average reduction of area decreases up to 300° C., but at higher temperatures there is again an increase, the

\* "Report on the Influence of Gauge Length and Section of Test-bar on the Percentage of Elongation." By Professor W. C. Unwin. London: Crosby, Lockwood & Son, 1903. Price 2s. 6d. net.

† *Verhandlungen des Vereines zur Beförderung des Gewerbflusses*, 1903, pp. 243-291.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1762-1770, 1812-1820; vol. xlviii. pp. 385-388.

results being influenced by the prolongation of the load. It is inferred that steel castings, while giving very satisfactory and fairly uniform tensile tests at ordinary temperatures, may present but little tenacity and uniformity at higher temperatures.

**Strength of Circular Steel Plates.**—Ensslin \* has conducted some experiments for the purpose of testing the elasticity of circular mild steel plates. A series of bending and tensile tests formed part of his programme, and the results of these are detailed.

**Standard Specifications.**—W. R. Webster and E. Marburg† review recent progress in standardisation of specifications for iron and steel in England and America.

**Specifications for Cast Iron.**—The standard specifications for foundry pig iron, prepared by a Committee of the International Association for Testing Materials, refer to the analysis, method of sampling, allowances and penalties, the bare analysis of grades, &c. These specifications have been the basis of much discussion by R. Moldenke, R. Job, E. S. Cook, and others at the Atlantic City meeting of the American Institute of Mining Engineers.‡ W. Wood and others dealt with specifications for cast-iron pipe, and H. Souther dealt with the proposed standard specifications for grey iron castings. Either reverberatory or cupola-melted metal is allowable. The sulphur limit is defended, and the requirements as to physical properties are discussed. The size of the arbitration test-bar has been fixed at  $1\frac{1}{2}$  inch square, but for ordinary tests a  $1\frac{1}{4}$ -inch bar is used. The casting conditions for test-bars are of utmost importance.

A committee of the American Society for Testing Materials has issued§ a proposed specification for cast-iron railway wheels.

**Steel Specifications.**—Extracts from the specification of the Prussian State Railways are given|| for the quality and testing of material for rolling stock.

\* *Dingler's Polytechnisches Journal*, vol. cccxviii. pp. 705-707, 721-726, 785-786, 791-796.

† *Transactions of the American Institute of Mining Engineers*, February 1904.

‡ *Ibid.*, February 1904; *Iron Age*, February 25, 1904, pp. 30, 34, 47, 48, 69.

§ *Iron Trade Review*, February 18, 1904, pp. 65-66.

|| *Engineering*, vol. lxxvii. pp. 66-68.

In connection with the contracts for driving tunnels under the North and East rivers at New York, the specifications for the materials required have been published.\* As the work will have to be carried on in very loose silt, it may be necessary to sink screw piles to a depth of 150 feet in places. The specifications refer to the iron castings for these piles and the tunnel linings, and also to the structural steel.

The specifications for the superstructure of the Blackwell's Island bridge across the East River, New York, have been published.† The chemical requirements for nickel steel for eyebars pins, plates, &c., rivet steel and castings, call for a maximum of 0·04 to 0·05 phosphorus in basic steel or 0·04 to 0·08 in acid steel, a maximum of 0·04 to 0·05 of sulphur, and a minimum of 3·5 per cent. of nickel. Tensile tests and bending tests are given in detail. For eyebars and pins the tensile tests range from 85,000 to 105,000 lbs., elastic limit from 50,000 to 52,000 lbs., elongation 18 to 20 per cent. in 8 inches, and reduction of area 35 to 45 per cent.

**Rails.**—In a paper read by W. Ast ‡ before the Verein deutscher Eisenbahnverwaltungen, questions relating to rails, rail fastenings, ties, bridges, &c., were considered. The author draws attention to the evident inadequacy of the present customary mechanical tests for affording satisfactory information on the wear of rails in practice. The actual section of the rail is also a matter of much importance, and the author gives details of one shape in use on the railways of the kingdom of Saxony.

**Wrought Iron and Cast Iron Pipes.**—In a paper read by Janke § before the Verein zur Beförderung des Gewerbefleisses, the question of the relative suitability of welded wrought-iron pipes and of cast-iron pipes for the purpose of conveying water on a large scale was discussed at length. The physical properties and practical considerations connected with the use and construction of the two kinds of pipes are summarised, and generally the advantages connected with the use of the wrought-iron pipe are shown to be very considerable, especially as the diameter of the pipe increases beyond some 17 inches. Weldless rolled pipes do not come into consideration, as their

\* *Iron Age*, October 8, 1903, pp. 42–43.

† *Engineering News*, vol. 1. pp. 206–210.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1164–1165.

§ *Ibid.*, vol. xxiv. pp. 307–312.

maximum diameter is about a foot, and they are therefore too small for the purpose more especially under consideration.

In the subsequent discussion Ritter von Schwarz drew attention to the fact that when a cast-iron pipe gives way it does so suddenly, and the break is at once detected. In the case of a wrought-iron pipe, on the other hand, the danger is a far more insidious one, the pipe becoming worn little by little and in many places, so that there may have been a leakage of water for a long time before the loss is detected. Cast iron, too, rusts far more slowly than wrought iron, probably on account of the protecting action of the carbon and the silicon that are present. The cast-iron pipe being so much thicker than that of wrought iron, the danger from this source is consequently greatly reduced when a cast-iron pipe is used. Tarring at a blue heat the author does not consider efficacious in the case of a wrought-iron pipe, owing to its contraction on subsequent cooling. Other evidence for and against was given by other speakers.

**Armour Tests.**—It is considered that during the past year the gun has unmistakably scored in its unending duel with the armour plate. This is due to the capping of the projectile and improvements in explosives.\*

It is suggested † that there is a critical point for the velocity of armour-piercing projectiles at which the effect is produced. Above that velocity the projectile will break up without penetration.

\* *Engineer*, vol. xcvii. pp. 21-22.

† *Ibid.*, vol. xcvi. pp. 429-430.

## CHEMICAL PROPERTIES.

**Atomic Weight of Iron.**—About four years ago, Richards and Baxter, by the reduction of ferric oxide by hydrogen, obtained the value 55·883 ( $O = 16\cdot000$ ) for the atomic weight under consideration. G. P. Baxter \* has recently made new determinations of this atomic weight by comparison of ferrous bromide with the silver bromide produced by it, or, in other cases, the silver required to react with it. The average result was 55·870, a remarkably close agreement with the result of the other method.

**Oxygen and Sulphur in Cast Iron.**—R. Moldenke † considers that the greatest but least realised difficulty the foundry has to deal with is the presence of dissolved oxide of iron in the pig and scrap used. Ferro-manganese and aluminium are not altogether suitable or advisable as deoxidising agents, but possibly ferro-titanium may be advantageous. At any rate it offers a field for investigation now that the methods of controlling sulphur are known.

J. E. Johnson, jun., ‡ suggests a test for the effect of silicon in neutralising sulphur in cast iron.

**Red-Shortness.**—G. A. Forsberg § discusses red-shortness, and notes the many attempts that have been made to ascertain the cause of this defect in iron. It has been assumed that if a plate fractures or shows cracks at the edges when punched at a red heat, it is due to red-shortness. Swedish iron is so pure that it was considered that this objectionable behaviour could not be due to the presence of sulphur, or of other objectionable impurities. It was thought to be due to other causes, a variety of which are enumerated. The author himself considers

\* *Zeitschrift für Anorganische Chemie*, vol. xxxviii. pp. 232-245.

† *Iron and Steel Metallurgist*, vol. vii. pp. 26-29.

‡ *American Machinist*, vol. xxvi. pp. 1451-1453.

§ *Jernkontorets Annaler*, vol. lviii., pp. 82-91.



that it is due to the impurities that are present, and he gives fourteen analyses of pig iron and malleable iron as proof of his contention. These showed that irons free from sulphur and copper, or with but traces of these, and containing little silicon and manganese, gave a malleable iron entirely free from red-shortness if not made into malleable iron in the forge with a blast temperature exceeding 75° C. Red-shortness only begins to be evident when the sulphur contents reaches 0.009 or 0.010. As the sulphur contents increases so does the degree of red-shortness which the metal shows, especially when in addition to these moderate quantities of sulphur, copper or arsenic also occurs in the pig iron. It is therefore not due to the presence of oxides. If, he adds, a pig iron low in sulphur gives a malleable iron which proves to be red-short, then in addition to sulphur too much copper will probably also be found to be present. In exceptional cases it may be arsenic alone that is also present, or both this and copper. Greater care is now taken in testing the iron for red-shortness than used formerly to be the case.

**Corrosion of Iron and Steel.**—C. L. Norton \* gives the further results of tests on the protective properties of Portland cement concrete applied to steel. Previous tests have shown that rust-free steel is thoroughly protected, and further experiments have shown that rusted steel is similarly protected, and that the corrosion does not extend as long as the cement or concrete is in good condition. Even cinder concrete is a good protector, despite suggestions as to the deleterious effect of any sulphur it might contain. It is only requisite that the concrete should be wet and thoroughly well mixed before it is applied, so as to form a good coherent coating.

H. Rinne † refers to the numerous attempts that have been made to ascertain the exact causes of boiler corrosion. It is often put down to the fault of the metal of which the boiler is made. The author considers that the open-hearth ingot metal which is used in modern boiler construction is not in any way in fault when a boiler corrodes. The air that enters with the feed-water plays a very important part in such corrosion. A boiler that corrodes under ordinary circumstances, may cease to be attacked if the feed-water is first freed from contained air. In addition to air, thermo-couples and consequent galvanic action no doubt are important in their effects. The author contends that if a

\* Report of the Insurance Engineering Experiment Station; *Engineering News*, vol. li. pp. 29-30.

† *Stahl und Eisen*, vol. xxiv. pp. 82-89, with two illustrations.

proper feed-water is employed, free from air and carbon dioxide, and if the boiler is blown off frequently enough, it would never show signs of corrosion.

Vogt\* deals with the phenomenon of corrosion of the steel plates of boilers, considering the effects of the soluble substances contained in the feed-water. The necessity for material of uniform composition for boiler construction is emphasised.

Diegel† refutes the commonly accepted theory that impure metals in sea-water corrode faster than pure ones. An addition of phosphorus to zinc-bronze has been shown to improve its capacity for resisting the action of sea-water, and its effect is the same upon iron. To determine the influence of phosphorus and nickel in retarding corrosion the author suspended some mild-steel plates in the open harbour at Kiel, and others in a tank of sea-water, the contents of which was kept at a constant level, and frequently changed. Some of the plates were of widely varying composition, and these were connected in pairs by metallic means, in order to test the effect of the galvanic action. Other plates were suspended singly, without metallic contact of any kind. In the case of phosphoric steel the results showed that corrosion is more rapid the lower the percentage of phosphorus, and that a very small difference in the proportion of phosphorus amounting to 0.08 per cent. is sufficient to set up a destructive action upon the plate forming the anode of the couple. With a greater difference than this in the phosphorus contents, the corrosive effect does not continue to show much increase. The isolated plates were also found to have lost in weight in proportion to their phosphorus contents. With 0.01 per cent. the loss in twelve months was 7 grammes on 16 square inches of surface, while with 1.08 per cent. it amounted to 4.9 grammes. The effect of the sea-water in the open harbour was just about double that of the water in the tanks. The influence of nickel was determined in the same way, with the result that when a piece of high-nickel steel is in contact with a piece of low-nickel steel of the same superficies the high-nickel steel is protected, while the other is more strongly attacked than if isolated. With 6 per cent. nickel and over, the alloy scarcely shows a sign of corrosion after twelve months. In the case of isolated nickel plates with 0.02 per cent. nickel the loss of weight was 6 grammes on 16 square inches of surface, and with 29.68 per cent. it amounted to 1.6 gramme on 16 square inches at the end of twelve months.

\* *Mittheilungen aus der Praxis des Dampfkessel-Betriebes*, 1903, pp. 683-686.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlvii. pp. 1122-1126.

As a sequel to papers on the manufacture and use of iron and steel pipe, some correspondence has ensued \* on the relative corrosion of those materials. As a result it is concluded that a considerably higher price might be paid for wrought iron.

M. Freund † describes the results of an investigation made to ascertain the cause of a cast-iron water-pipe becoming so seriously corroded that it finally fractured. The corroded portions of the pipe showed a quantity of a porous graphitic-like mass which on analysis gave :—

Carbon.	Silicon.	Phosphorus.	Iron.
8.10	9.3	6.5	46.18

The original metal contained per cent. :—

Carbon.	Silicon.	Phosphorus.
2.50	2.66	1.90

The whole of the silicon and phosphorus present in the graphitic mass was derived from the iron, and had nothing to do with the earth in which the pipe was embedded. The author thinks its origin was due to electric action, and he actually succeeded in producing a similar product in this way.

W. M. Hamlet ‡ discusses the protection of iron and other metal work.

**Ferro-manganese Slag.**—F. Wittmann § discusses the question of slag in the manufacture of ferro-manganese. Usually the slag is kept as basic as possible. Unfortunately no two persons are usually agreed as to exactly what is meant by this expression. The conditions are different in ferro-manganese manufacture from those connected with ordinary blast-furnace practice. The slag has also to act as the solvent for manganous oxide, and it is therefore not merely a question of its degree of fusibility. The yield of manganese depends in the first instance on the consumption of coke. If much coke is used a highly siliceous slag comparatively low in manganese may be obtained. Conversely, when the consumption of coke is low, a great deal of manganese may be present in the slag, even when it is of a very basic character. The numerous analyses of ferro-manganese slags, that are published without any statement as to the conditions under which they were produced, are therefore valueless for the purpose of ascer-

\* *Engineering News*, vol. I. pp. 286, 296, 318, 502-504.

† *Zeitschrift für angewandte Chemie*, January 8, 1904.

‡ Paper read before the Royal Society of New South Wales, August 5, 1903; *Chemical News*, vol. lxxxviii. p. 219.

§ *Stahl und Eisen*, vol. xxiv. pp. 14-16.

taining the best possible composition. Even though the percentage of manganese present remains the same, the composition of the slags varies very greatly, and unless the coke consumption is also given, very confusing results would be arrived at from the comparative consideration of the analyses. The author therefore compares analyses of eleven slags which were made under similar working conditions in the same blast-furnace. They contained :—

	Maximum.	Minimum.
Manganese . . . . .	23·33	12·17
Silica . . . . .	31·47	29·02
Alumina . . . . .	10·59	6·78
Ferrous oxide . . . . .	0·72	0·29
Lime . . . . .	45·62	34·30
Magnesia . . . . .	4·65	1·89
Baryta . . . . .	0·00	2·83
Sulphur . . . . .	1·32	0·42

The slag highest in manganese contained 37·03 per cent. of lime, and was produced in the manufacture of 80 per cent. ferro-manganese. That lowest in manganese contained 45·62 per cent. of lime, and was also made with 80 per cent. ferro-manganese. The other slags related to ferro-manganeses containing from 30 to 80 per cent. of manganese. The author plots the analyses in the form of a curve, and grouping lime, magnesia, and baryta together he shows that the slag takes up less and less of manganese oxide as the percentage of these other bases increases. At first the curve of solubility for the manganeous oxide drops very rapidly with the increase in the other bases, but after they reach about 44·5 per cent. the curve becomes almost a straight line, showing that a further addition of lime is useless.

# CHEMICAL ANALYSIS.

## CONTENTS.

	PAGE		PAGE
I. Analysis of Iron and Steel . . . . .	680	III. Fuel Analysis . . . . .	689
II. Analysis of Iron Ores and Slag . . . . .	687	IV. Gas Analysis . . . . .	690

### I.—ANALYSIS OF IRON AND STEEL.

**Ironworks Analysis.**—Detailed notes on some of the methods of chemical analysis used in Canadian ironworks are given by W. Dixon Craig.\*

General directions are given † for the analysis of high speed tool steel, showing an outline of the methods to be followed for determining carbon, tungsten, silicon, sulphur, phosphorus, manganese, titanium, nickel, and molybdenum.

Recent progress in the chemical analysis of iron and steel is described by O. Brunck. ‡

A. Kleine§ describes some modified forms of apparatus for use in ironworks laboratories. These comprise an improved distillation flask for the determination of arsenic, and a dissolving flask for sulphur determinations.

G. C. Davis|| mentions some of the troubles met with in samples of iron and coke sent for analysis. In part they are due to wrong methods of sampling, contamination of the sample, and poor packing. A humorous account is given of the condition in which many samples arrive. Some notes are then given on the necessity for care in drilling

\* *Journal of the Canadian Mining Institute*, vol. vi. pp. 288-300.

† *Engineering*, vol. lxxvi. p. 690.

‡ *Chemiker Zeitung*, vol. xxviii. p. 513.

§ *Stahl und Eisen*, vol. xxiv. p. 248, with one illustration.

|| Paper read before the Philadelphia Foundrymen's Association; *Iron Age*, December 17, 1903, p. 3.

the samples and on the selection of suitable methods of packing, but, as regards the latter point, some better system, combining ease and economy, is certainly wanted.

**Determination of Carbon.**—The colorimetric determination of carbon in high-carbon steel is described by G. Auchy.\*

E. Lecocq † gives an account of Hempel's method for the volumetric determination of carbon in iron and steel, describing the apparatus employed and the stages of the operation.

**Determination of Silicon.**—According to G. F. Horsley ‡ the great disadvantage of the ordinary nitro-sulphuric acid process for the estimation of silicon in forge iron lies in the liability towards explosive spurning—at least, this is his experience—towards the end of the preliminary evaporation to dryness. There is also an occasional tendency towards the formation of gelatinous silica. Experiments were therefore made, using various proportions of the three common acids, until a process was devised which is free from both these objections, and which he trusts is not well known already. To 1 gramme of forge iron add 10 cubic centimetres of dilute sulphuric (one part acid to four parts water) and 15 cubic centimetres of hydrochloric. Boil down till fumes of sulphuric anhydride are evolved. Cool, add 100 cubic centimetres of water and 10 cubic centimetres hydrochloric acid, and boil. Filter, and wash once with 5 cubic centimetres hydrochloric acid, and four times with hot water. Dry and ignite.

H. Lidholm § observes that ferro-silicon with 30 per cent. of silicon is not soluble in nitro-hydrochloric acid, and fusion with potassium hydrogen sulphate is also quite unsatisfactory. Sodium peroxide, however, gives good results. From 0.2 to 0.3 gramme of the ferro-silicon is mixed with 15 times the weight of a mixture consisting of one part potassium-sodium carbonate, and two parts of sodium peroxide. The mixture is transferred to a nickel crucible, and is then heated over a Bunsen burner. It is better, however, to mix the ferro-silicon and fusion mixture first, then to heat this to drive out moisture, and then to add the peroxide. The decomposition is complete in a few minutes. The crucible is then cooled, and placed in 200 cubic centimetres of

\* *Journal of the American Chemical Society*, vol. xxv. p. 999.

† *Revue Universelle des Mines*, vol. iii. pp. 228-237.

‡ *Chemical News*, vol. lxxxviii. p. 136.

§ *Zeitschrift für angewandte Chemie*, vol. xvi. pp. 1030-1031.

warm water, the fused mass dissolving readily. The solution is acidulated with hydrochloric acid, and then evaporated to dryness, the silica being subsequently determined in the ordinary way.

To determine sulphur in the alloy from 10 to 15 grammes of it must be taken for the determination. The silica is first separated in the manner described above, the iron separated, and the sulphuric acid remaining in the solution determined as usual.

**Determination of Manganese.**—According to G. von Knorre\* the sample of iron or steel is, as usual, dissolved in dilute sulphuric acid, oxidised with nitric acid, and the partially neutralised solution is boiled with excess of ammonium persulphate. It is now of the greatest importance to remove the excess of persulphate, and this may be effected by acidifying and strongly diluting the solution and then boiling for at least twenty minutes. When cold, the precipitated manganese peroxide is at once dissolved (without previous filtering) by means of a not too large amount of a standard solution of hydrogen peroxide, and the excess of this is then without delay titrated with standard permanganate. The process may be employed in the presence of small quantities of nickel, copper, and phosphoric acid.

A number of methods for the determination of iron and manganese are discussed.† These include that of G. von Knorre, who precipitates manganese by an excess of persulphate at a boiling temperature. This precipitate always carries some iron down with it, and various precautions are necessary. The manganese in the precipitate is determined by titration with hydrogen peroxide. Details of the method are given. Another method discussed is the ordinary acetate one. A. Mittasch‡ has experimented with this, and makes various observations concerning it, giving a modified method that in his opinion leads to accurate results. The electrolytic methods of separation of iron and manganese are also very briefly referred to, it being considered that these matters are wanting in simplicity and applicability as compared with the other methods usually employed.

J. Malette§ adds drop by drop to 20 grammes of the steel filings in which the manganese is to be determined, 20 cubic centimetres of nitric acid of 1.2 specific gravity. The whole is heated to boiling, allowed to cool, and diluted with water to 100 cubic centimetres.

\* *Zeitschrift für angewandte Chemie*, vol. xvi. pp. 905-911.

† *Stahl und Eisen*, vol. xxiv. p. 249.

‡ *Zeitschrift für analytische Chemie*, vol. xlii. p. 492.

§ *La Revue Technique*, vol. xxiv. p. 327; *Stahl und Eisen*, vol. xxiii. p. 1204.

Twenty cubic centimetres of this is then transferred to a 50 cubic centimetre flask, and 15 cubic centimetres of hydrochloric acid (36° B<sub>é</sub>), free from nitric acid, added. This is then heated on the sand bath to 90° C., and about 1 gramme of red lead which has been previously ignited is then added, the solution is heated for 3 or 4 minutes, more red lead is added, rapidly cooled, diluted to 50 cubic centimetres, filtered through asbestos, and the solution compared colorimetrically with a standard solution of permanganate containing 1.582 gramme of the salt to the litre. The time required is about two hours.

**Determination of Sulphur.**—S. S. Knight\* mixes 2 grammes of the sample with 1 gramme of iron reduced by hydrogen in a porcelain crucible, and covers the mixture with another gramme of the pure iron. The crucible is then heated as high as possible over a blow-pipe flame for ten minutes, and, after partial cooling, is transferred to the evolution apparatus, in which the metal is dissolved in hydrochloric acid. An ammoniacal solution of cadmium chloride is used as the absorbent, and is titrated with iodine solution. The process takes half an hour.

W. G. Ireland† gives experiments to prove further that cast iron samples should be annealed before the determination of sulphur. Without annealing sulphur seems to disappear in the course of time from borings, but this is ascribed to some chemical change and not to absolute loss. A steel standard is preferred to a cast iron standard.

G. T. Dougherty‡ considers that sulphur may exist in three forms in cast iron, one being evolved as sulphuretted hydrogen on treatment with hydrochloric acid, one being evolved as an organic compound on similar treatment, and the remainder being left in the insoluble residue. The second and third varieties seldom exist together, and both are converted into the first variety by annealing. One kind of iron, however, is described by the author, in which annealing did not affect the conversion.

A number of comparative determinations have been made by A. Grabe§ to ascertain the degree of accuracy attainable by the Wiborgh method for the determination of sulphur in iron. These showed that when this method was properly carried out it gave results which

\* *Iron Age*, February 25, 1904, p. 70.

† *Iron Trade Review*, December 3, 1903, p. 69.

‡ *Iron Age*, March 31, 1904, p. 3.

§ *Teknisk Tidskrift, Kemi och bergsvetenskap*, vol. xxxii. pp. 89-92; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. p. 645.



were quite adequate for practical purposes. It was compared with the barium chloride method, and sixteen comparative results are given for various kinds of pig iron. The sulphur contents varied from 0.010 per cent. to 0.100. The greatest difference observed between the two methods was 0.005 per cent.

**Determination of Tungsten.**—E. Kuklin \* observes that only gravimetric methods are employed for the determination of tungsten in steel. He now describes a volumetric method which he states to be both rapid and accurate. It depends upon the fact that the metatungstic acid, which is formed by the action of acids on tungstic acid, is reduced by zinc to  $\text{WO}_2$ , and that this is capable of being re-oxidised by potassium permanganate to  $\text{WO}_3$  according to the reaction  $5\text{WO}_2 + \text{Mn}_2\text{O}_7 = 5\text{WO}_3 + 2\text{MnO}$ .

The author dissolves 2 grammes of the steel in a mixture of equal parts of sulphuric acid (1.84) and phosphoric acid (1.70) with three times the quantity of water. To this three cubic centimetres of potassium permanganate is added drop by drop to maintain a lasting pink coloration, the solution being heated to render it permanent. It is then cooled, transferred to a measuring flask, and half of it is used for the titration. Two hundred cubic centimetres of dilute sulphuric acid (1:3) is then added, and about 40 grammes of zinc turnings, the whole being heated. When the solution has the colour of port wine it is allowed to cool down in a current of carbon dioxide. After cooling the excess of zinc is filtered off, and the solution titrated with permanganate until the usual coloration results. By this determination the total percentage of iron and tungsten is obtained. In the other half of the original solution only the iron is determined, either by the Reinhardt method or by the use of stannous chloride and iodine, the difference between the two results representing the tungsten that was also present. Ferro-tungsten is not readily completely soluble in acids, so when the tungsten has to be determined the finely divided sample should be charged into a platinum crucible containing molten ammonium nitrate, the nitrates are decomposed by heating, and the residual oxides are fused with potassium-sodium carbonate in the ordinary way.

**Determination of Vanadium.**—Several methods for the determination of vanadium in iron and steel are described and considered.†

\* *Stahl und Eisen*, vol. xxiv. p. 27.

† *Ibid.*, vol. xxiii. pp. 1203-1204.

The method now most commonly employed consists in precipitating the vanadium as ammonium-meta-vanadate from a solution saturated with ammonium chloride. The vanadate is insoluble in this solution, and the crystalline precipitate is filtered, washed with ammonium chloride solution, and then with alcohol. Subsequent ignition converts it into vanadium pentoxide. When only small quantities of vanadium are present this method presents several difficulties. Truchot has therefore suggested the use of an electrolytic method instead. He found that from a hot and feebly ammoniacal solution of sodium vanadate the vanadium was precipitated electrolytically as hydroxide or as a mixture of various hydroxides, which on slow ignition are converted into the pentoxide  $V_2O_5$ . The material under examination is fused with sodium carbonate, dissolved in cold water, filtered, the filtrate feebly acidulated with sulphuric acid, boiled to eliminate the carbon dioxide, ammonia added until the reaction is slightly alkaline, heated to  $80^\circ$  to  $85^\circ$  C., and then electrolysed with a current of from 2 to 2.5 volts and 0.3 ampère for eight to ten hours. The solution should be about 200 cubic centimetres in volume. During this period about 0.012 to 0.050 gramme  $V_2O_5$  can be precipitated in this way. An iridescent yellowish-brown deposit will be observed on the cathode, and this is ignited and weighed. The precipitate readily takes up moisture from the air. The presence of an excess of ammonia or of hydrochloric acid in the electrolyte are disadvantageous. In the criticism of this method it is pointed out that the small quantity of material, the necessarily weak currents, and the length of the electrolysis render the method not altogether advisable from a practical point of view. The method may be used for the qualitative determination of vanadium. The deposit obtained as above is fused with a small quantity of bisulphate and a few crystals of strychnine added. A violet-red colour then ensues. Phenol gives a dark green coloration. As small a quantity as 0.0001 gramme vanadic acid can be detected in this way.

Another method is that of Cormimbœuf, who employs a modification of the Roscoe method. The vanadium in the material under examination is in the first instance converted into sodium or potassium vanadate which is dissolved out with water, filtered, the filtrate acidulated with acetic acid and an adequate quantity of lead acetate is added. This precipitates the whole of the vanadic acid from the solution. Unfortunately this lead precipitate is not of constant composition and has to be further treated. It is brought on to a weighed filter, washed with water acidulated with acetic acid, dried, and weighed.

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A weighed portion is then dissolved in dilute nitric acid, some concentrated sulphuric acid added to precipitate the lead, diluted, filtered, evaporated, and ignited to a dull red. This is stated to leave pure vanadium pentoxide, which is then weighed. The whole operation lasts something less than twenty-four hours.

**Determination of Titanium.**—S. Burmann \* discusses the determination of titanium in iron ores. The author observes that the difficulties connected with this determination are well known. The various methods may be of themselves apparently above reproach, but in practice they are almost unworkable. This appears to be due to two important points being insufficiently allowed for. The first of these consists in the difficulty that is experienced in bringing the titanium completely into solution, and the second the difficulty of subsequently precipitating it in a form that can be easily filtered and readily washed properly. The latter difficulty is due to the fact that it is necessary to endeavour to obtain the flocculent ortho-titanic hydroxide  $\text{TiO}_4\text{H}_4$ , the amorphous meta-hydroxide being one of the most difficult of all substances to filter off completely. This latter forms, however, both when acid titanium solutions are boiled and also when acids are added to most of the titanium compounds. The author suggests the following as being a simple method which is accurate enough for practical use:—From 0.5 to 1 gramme of the sample is finely powdered and is heated to redness in a current of hydrogen for forty-five minutes. After cooling in hydrogen the sample is transferred to a beaker containing 8 to 10 cubic centimetres of hydrochloric acid and 200 of water. It is not advisable to use sulphuric acid. The iron passes into solution, the titanium remaining with the residue undissolved. This residue is then filtered, washing being avoided as far as possible. It is then burnt in a platinum crucible. It is fused in this with ten times its weight of sodium carbonate and subsequently extracted with water. This dissolves out phosphoric acid and some of the alumina, silica, &c. The neutral sodium titanate that had been formed is decomposed by the water with the formation of sodium hydroxide and the acid sodium titanate  $2\text{Na}_2\text{O}, 9\text{TiO}_2, 5\text{H}_2\text{O}$ . The latter salt is insoluble in water. If potassium carbonate had been used for the fusion a soluble salt would have been produced. It is found that during the fusion process the sodium titanate settles on the bottom of the platinum crucible, and it

\* *Teknisk Tidskrift, Kemi och bergsvetenskap*, vol. xxxii. pp. 76-77; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. p. 743.

is therefore desirable to empty the contents into a platinum dish, allow them to cool, and then to pulverise them. This greatly facilitates the subsequent extraction with water. Such wash water as is used must contain sodium carbonate. The filter paper is burnt, after separation from its contents, in a weighed platinum crucible. The weighed residue is transferred to a beaker, acidulated with hydrochloric acid, heated, and the titanium that has passed into solution is precipitated by a solution of pure sodium hydrate. After filtering and washing only pure titanium oxide with perhaps a little iron remains on the filter. This is burnt, fused carefully in a platinum crucible with 10 grammes of potassium hydrogen sulphate until the solution is complete, which may take an hour to effect, cooled and dissolved in 400 cubic centimetres of cold water, with the addition of 10 grammes of an alkaline bisulphite to reduce the ferric oxide to the ferrous form. It is then filtered, the solution neutralised until faintly acid, sodium or ammonium acetate added to bind the free sulphuric acid, and the acetic acid solution so obtained is boiled, when flocculent titanium hydroxide is at once precipitated. Some platinum will have been dissolved after the last fusion, and this will be precipitated with the titanium unless precipitated by hydrogen sulphide. The difference in weight of the platinum crucible would afford information as to this source of error.

## II.—ANALYSIS OF IRON ORES AND SLAG.

**Analysis of Minette.**—A. Wencélius\* dissolves 2.5 grammes of the ore in a small Erlenmeyer flask by the aid of hydrochloric acid of 1.19 specific gravity, filters, burns the filter, fuses the residue with soda, takes up with hydrochloric acid, and evaporates both filtrates to dryness to get rid of the silica. The filtrate is made up to 500 cubic centimetres. Of this 100 cubic centimetres is titrated by the Reinhardt method to determine the iron contents. Next a further quantity of 100 cubic centimetres is utilised for the determination of the alumina by the Campredon method, being first diluted to 500 cubic centimetres, then exactly neutralised with ammonia, 4 cubic centimetres of hydrochloric acid added, and then in the cold 20 cubic centimetres of a 10 per cent. solution of sodium phosphate is added drop by drop, and 15 cubic centimetres of glacial acetic

\* *Revue générale de Chimie pures et appliquées*, vol. vi. p. 400; *Stahl und Eisen*, vol. xxiv. p. 403.

acid, heated, boiled for fifteen minutes, filtered, washed with boiling water, dried, and ignited. The aluminium phosphate precipitate contains 41.847 per cent. of  $\text{Al}_2\text{O}_3$ . To determine the lime, the iron, aluminium, and manganese are precipitated, dissolved, and re-precipitated with ammonia and bromine water, the solution and re-precipitation being necessary, as otherwise lime passes with the precipitate. The lime in the filtrate is determined in the ordinary way.

**Determination of Iron.**—A. Skrabal \* has written further articles defending the purity of electrolytic iron deposited from an ammonium oxalate solution in the method recommended by him for preparing pure iron for standardising permanganate.

The methods of preparation of pure iodine for use in standardising that have been proposed by Stas, Meineke, and Ladenburg are not sufficiently simple. L. de Koninck † has elaborated an easier method which depends on the reaction:— $6\text{KI} + 5\text{K}_2\text{Cr}_2\text{O}_7 = 8\text{K}_2\text{CrO}_4 + \text{Cr}_2\text{O}_3 + 6\text{I}$ . This reaction is not affected by any impurities that may happen to be present in the potassium iodide employed. The dried salts are powdered and heated together in the proportion of one I to 1.5 or 2 of  $\text{K}_2\text{Cr}_2\text{O}_7$ , a retort being employed. When no more violet fumes are evolved the heating is stopped. From 100 parts of potassium iodide, at least 73 parts of iodine are obtained in this way. It is best to condense the iodine vapours direct in a weighed Erlenmeyer flask of about 150 cubic centimetres capacity. The iodine collected is weighed, dissolved with the aid of 1.5 to twice its weight of potassium iodide and diluted to a decinormal strength.

O. Kühling ‡ discusses the use of potassium tetraoxalate for standardising purposes. The use of this salt has led to considerable discussion, some favouring it and others being averse to its use. The author considers that these varying opinions are due to the fact that some dry the salt over sulphuric acid before using it, while others employ it in the air-dry state. By the first method constant results are not possible. The author describes how the salt should be prepared to render its use free from objection. Its active reaction with permanganate corresponds exactly with the formula  $\text{C}_2\text{O}_4\text{HK} + \text{C}_2\text{O}_4\text{H}_2 + 2\text{H}_2\text{O}$ .

S. O. L. Sørensen § prefers the normal sodium oxalate for standard-

\* *Zeitschrift für analytische Chemie*, vol. xlii. pp. 741-744; vol. xliii. pp. 97-98.

† *Bull. Acad. roy. Belgique*, vol. xvii. p. 15; *Stahl und Eisen*, vol. xxiii. p. 1392.

‡ *Zeitschrift für angewandte Chemie*, vol. xvi. p. 1030.

§ *Zeitschrift für analytische Chemie*, vol. xlii. p. 333.

ising purposes. The author describes how this salt should be prepared. Both these potassium and sodium salts are stated to keep well.

A. Leclère \* describes a method of separating alumina from iron by the aid of formic acid.

**Analysis of Basic Slag.**—O. Böttcher † gives a method for the determination of the phosphoric acid soluble in citric acid in basic slags. The mixture of the basic slag extract should not be heated for long in the citrate solution.

The determination of phosphoric anhydride in basic slag is discussed by T. Knösel. ‡

### III.—*FUEL ANALYSIS.*

**Determination of Sulphur.**—The following method for the rapid estimation of sulphur in coal or coke, described by J. D. Pennock § and D. A. Morton, has been found to give accurate results and at the same time enables a chemist to make as many as three determinations in an hour. Introduce into a soft steel crucible of 40 cubic centimetres capacity 16 grammes sodium peroxide and 0·7 gramme coal (or 11·5 grammes peroxide and 0·7 gramme coke) and mix thoroughly. Cover and place the crucible on its stand in a beaker of water, in such a way that the lower half only is immersed. Ignite by thrusting a hot wire through a hole in the crucible cover. After three minutes tip the crucible on its side and allow the contents to dissolve, then remove the crucible and add hydrochloric acid. Boil the solution and add ammonia until slightly in excess, and then 15 cubic centimetres barium chromate solution consisting of 23 grammes chromate in 80 cubic centimetres concentrated hydrochloric acid and 920 cubic centimetres water. Add sufficient water to make 200 cubic centimetres, then ammonia in excess, and boil vigorously. Filter, wash precipitate, and add 1 gramme potassium iodide crystals to the filtrate. Cool the filtrate to 30° C., add 5 cubic centimetres hydrochloric acid, and titrate with a decinormal solution of sodium thiosulphate.

G. Kroupa || refers to recent papers on the determination of sulphur in coal, pointing out that the first to propose the use for this purpose

\* *Comptes Rendus*, vol. cxxxviii. pp. 146-147.

† *Chemiker Zeitung*, vol. xxvii. p. 1225.

‡ *Ibid.*, vol. xxviii. pp. 38-39.

§ *Journal of the American Chemical Society*, vol. xxv. pp. 1265-1269.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. pp. 538-540.

of sodium peroxide was S. W. Parr. The sole difficulty connected with the use of this method lies in the necessity for the employment of a suitable form of apparatus. For coke a nickel crucible provided with a lid, and of some 30 cubic centimetres capacity, is sufficient, but in the case of coal the oxidation is always accompanied by an explosion, and a suitably constructed bomb becomes necessary. The sodium peroxide method has been described in full detail by C. Sundström.\* Some observations by G. L. Rhead are also referred to.

O. Pfeiffer † describes the Eschka method of determining sulphur as applied to fuel analysis.

**Coal Ash.**—The laboratory examination of coal ash is described by J. W. Cobb.‡

**Coal Analysis.**—Brauss§ discusses the elements of fuel analysis and gives formulæ for the calculation of the quantity of air required for combustion.

A. Meurice and L. Denoël|| give detailed results of the analyses of borings taken in the Campine district of Belgium. They recommend the adoption of certain precautions in dealing with samples of this nature, by the neglect of which very untrustworthy results may be obtained.

#### IV.—GAS ANALYSIS.

**Fractional Combustion.**—O. Brunck ¶ has carried out experiments with the fractional combustion of gases by means of palladium asbestos. The experiments with hydrogen and methane gave good results.

\* *Journal of the American Chemical Society*, vol. xxv. pp. 184-186.

† *Chemiker Zeitung*, vol. xxviii. p. 38.

‡ *Journal of the Society of Chemical Industry*, vol. xxiii. pp. 11-13.

§ *Zeitschrift der Kälte Industrie*, 1903, pp. 170-172.

|| *Annales des Mines de Belgique*, vol. viii. pp. 1217-1232.

¶ *Zeitschrift für angewandte Chemie*, vol. xvii. pp. 695-704.

## STATISTICS.

## CONTENTS.

	PAGE		PAGE
I. United Kingdom . . . . .	691	XII. Mexico . . . . .	706
II. Australasia . . . . .	694	XIII. Norway . . . . .	707
III. Austria-Hungary . . . . .	694	XIV. Portugal . . . . .	707
IV. Belgium . . . . .	696	XV. Roumania . . . . .	707
V. Canada . . . . .	697	XVI. Russia . . . . .	708
VI. China . . . . .	698	XVII. South America . . . . .	712
VII. France . . . . .	699	XVIII. Spain . . . . .	713
VIII. Germany . . . . .	700	XIX. Sweden . . . . .	714
IX. Holland . . . . .	704	XX. United States . . . . .	715
X. India . . . . .	705	XXI. Comparative Tables . . . . .	720
XI. Japan . . . . .	706		

## I.—UNITED KINGDOM.

**Mineral Statistics.**—According to the official statistics\* the British production of iron ore in 1903 was 13,715,645 tons. The output of coal in 1903 amounted to 230,334,469 tons.

**Iron Trade Statistics.**—The British Iron Trade Association† returns the production of iron and steel in the United Kingdom during 1903 as follows:—

	Tons.
Pig iron . . . . .	8,811,204
Acid open-hearth ingots . . . . .	2,613,274
Basic open-hearth ingots . . . . .	510,809
(Total open-hearth ingots) . . . . .	3,124,083
Acid Bessemer steel . . . . .	1,316,915
Basic Bessemer steel . . . . .	593,103
(Total Bessemer steel) . . . . .	1,910,018

\* *Mines and Quarries: General Report and Statistics for 1902*, Part I. p. 10.

† *Iron and Coal Trades Review*, vol. lxviii. pp. 908-910.



**Imports and Exports.**—The Board of Trade\* returns for 1903 show that during the year the exports amounted to 3,571,373 tons, and the imports to 1,282,899 tons of manufactured iron and steel. The principal headings under which these totals were distributed were:—

	Tons.
Pig iron . . . . .	1,065,473
Steel bars, angles, rods, &c. . . . .	156,830
Wrought iron bars . . . . .	110,625
Rails . . . . .	608,146
Chairs, sleepers, &c. . . . .	120,010
Wire . . . . .	60,006
Pipes . . . . .	105,987
Nails, screws, bolts, &c. . . . .	34,632
Galvanised and corrugated sheet . . . . .	352,446
Black-plates . . . . .	65,266
Steel sheets, under $\frac{1}{4}$ -in. thick . . . . .	109,014
Tinned plates and sheets . . . . .	293,147
Tires, axles, wheels, &c. . . . .	36,399
Miscellaneous manufactures . . . . .	63,549

The imports comprised 136,646 tons of pig and puddled iron; 186,630 tons of iron bars, angles, &c.; 145,329 tons of girders; 274,056 tons of unwrought steel; 73,759 tons of rails; and 192,524 tons of steel bars, angles, and various sections.

**Accidents in Mines and Quarries.**—Tables have been published† in connection with the general report on mines and quarries showing the number of fatal accidents and deaths that have occurred in and about the mines and quarries of the United Kingdom during the year 1903. The number of fatal accidents at all mines under the Coal Mines Act was 1036, or 117 more than in the previous year. The total number of deaths involved was 1072, or 48 more than in 1902.

**Iron Ore.**—According to the forty-first Annual Report of C. E. Müller and Company, the production of Cleveland ore in 1902 was 5,401,932 tons, while that for 1903 is estimated at 5,500,000 tons. The total ore production of Great Britain in 1902 is given as 13,426,004 tons. In 1903 there were imported into Great Britain 6,313,236 tons of foreign iron and manganiferous ores, of which 4,945,160 came from Spain.

**Open-Hearth Furnaces.**—Statistics of the number, size, and linings

\* *Iron and Coal Trades Review*, vol. lxviii. pp. 116-117.

† *Mines and Quarries: General Report and Statistics for 1903, Part I.*

of the open-hearth furnaces in Great Britain have been published,\* including the following summarised table:—

	1 to 5 Tons.	5 to 10 Tons.	10 to 20 Tons.	20 to 30 Tons.	40 to 70 Tons.	50 Tons and over.	Acid Furnaces.	Basic Furnaces.	Firms.
Scotland . . . . .	2	5	6	67	36	21	120	17	17
North-East Coast . . . . .	6	6	8	37	26	34	96	21	14
South and North Wales . . . . .	1	9	6	61	29	5	91	16	24
Sheffield and Leeds . . . . .	2	4	26	28	15	1	66	10	22
Lancashire and Cumberland . . . . .	3	6	3	16	8	2	31	7	9
Staffordshire, &c. . . . .	1	2	9	20	4	1	13	24	8
<b>Totals . . . . .</b>	<b>15</b>	<b>32</b>	<b>58</b>	<b>229</b>	<b>118</b>	<b>64</b>	<b>417</b>	<b>95</b>	<b>94</b>

**Coal.**—A return has been published † giving statistics showing the quantity of coal exported from the various ports of the United Kingdom to countries abroad during each quarter of the years 1902 and 1903, as well as the quantity shipped at each port for the use of vessels on foreign voyages during the same periods. The return also contains a summary statement, showing the shipments of coal from the principal districts of the United Kingdom to various groups of foreign countries and British Possessions during each quarter of 1902 and 1903.

The second report of the Royal Commission on Coal Supplies ‡ and the evidence § taken by the Royal Commission between the 27th January and the 21st October 1903, upon which the report is based, have been published.

R. A. S. Redmayne || gives a historical review of the coal industry in the United Kingdom, tracing its development from the earlier days of its supremacy through the period of extended growth of labour-saving machinery and then treating the subject in its present economic aspects with special reference to labour conditions and the future.

**Iron and Steel Industries.**—A memorandum, drafted by the secretary to explain the significance of some of the points for witnesses

\* *Iron and Coal Trades Review*, vol. lxviii. pp. 470a, 470b, 471.

† *Coal Exports, &c., Return*. 96 pages. (Price 3½d.)

‡ *Royal Commission on Coal Supplies. Second Report. Vol. I., The Report*. [Cd. 1990.] (Price 1d.)

§ *Ibid., Vol. II., Minutes of Evidence and Appendices*. [Cd. 1991.] (Price 3s. 6d.)

|| *Engineering Magazine*, vol. xxvi. pp. 20-32, 193-204, 400-409.

to be submitted to the committee on the iron and steel trade section of the Tariff Commission, has been published.\*

W. P. Digby † presents some statistics of the iron and steel industries of the world in view of the ironfounders' standpoint in Britain and Germany in respect of iron ore supplies and of pig iron production in Britain and the United States. Import and export trades are also compared, and values are referred to food as a basis. Bennett H. Brough, in the course of the discussion, pointed out that quantities alone could not be relied upon, but that monetary value must be considered in relation to iron or to coal, which vary so enormously in value according to their compositions.

## II.—AUSTRALASIA.

**Mineral Statistics of Queensland.**—According to the official statistics ‡ the coal production of Queensland in 1903 was 507,801 tons, valued at £164,798. There were also produced 9808 tons of iron ore, 1320 tons of manganese ore, and 197 tons of wolfram.

## III.—AUSTRIA-HUNGARY.

**Mineral Statistics.**—The Austrian Government has published§ the second part of the Statistical Year-Book of the Minister of Agriculture containing reports on the condition of the mines, the petroleum statistics, and the fire-damp statistics. The volume, which covers 315 pages, has been drawn up in the manner adopted in previous years. In 1902 there were in Austria 1349 winding and pumping engines with 104,386 horse-power. Further, there were 1376 steam engines with 56,448 horse-power used for driving fans, dressing machinery, air compressors and dynamos, and in the smelting works 74 blowing engines with 25,966 horse-power. In Austria there were 520 mines and 59 smelting works in operation, and there were employed in mining 140,860 persons, and in smelting 7180 persons. Of the total

\* *Engineer*, vol. xvii. p. 293.

† *Journal of the Society of Arts*, vol. lii. pp. 543-561.

‡ *Annual Report of the Under Secretary for Mines; Board of Trade Journal*, vol. xlv. p. 260.

§ *Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums*, Part II., 1903 (Vienna: Government Printer).

workpeople 44·66 per cent. were employed in Bohemia, 20·82 per cent. in Silesia, 11·88 per cent. in Styria, and 9·03 per cent. in Moravia. The total number of workpeople employed in Austria in 1902 included :—

Collieries . . . . .	66,582
Brown-coal mines . . . . .	56,269
Iron ore mines . . . . .	5,358
Graphite mines . . . . .	1,296
Ironworks . . . . .	5,104
Other metallurgical works . . . . .	2,076

Altogether 140,860 workpeople were employed in mining, a decrease of 5·64 per cent. as compared with the similar number for the preceding year. At the smelting works 7180 were employed, a decrease of 13·84 per cent. During the year there were 216 fatal accidents in the mines and 4 in the smelting works. The Galician petroleum statistics show that the petroleum production amounted to 520,847 tons, and the ozokerite production to 523,501 tons. During the year there were in Austria 8 fire-damp explosions and no coal-dust explosion, 24 workmen being killed and 8 seriously injured. Of these explosions 6 occurred in collieries, 1 in a brown-coal mine, and 1 in an ozokerite mine.

Details are given\* as to the production of the collieries of the Ostrau-Karwin coal-field in 1903. Altogether 11 companies raised 6,390,753 tons of coal, made 882,270 tons of coke and 37,394 tons of briquettes, and gave employment to 38,760 workpeople and 1423 officials. The chief colliery undertakings and their outputs were as follows :—

Undertakings.	Output. Metric Tons.
Witkowitz collieries . . . . .	1,593,302
Kaiser-Ferdinand Nordbäk collieries . . . . .	1,322,280
Graf Larisch-Mönnich . . . . .	804,800
Erzherzog Friedrich . . . . .	640,700
Graf von Wilezek . . . . .	545,537

An article on the Galician petroleum industry has been published.† The production has risen from 600 tons in 1878 to 576,000 tons. There are 1888 productive wells.

**Brown Coal in Bohemia.**—The production of the Bohemian brown

\* *Honické a hutnické listy*, No. 2, 1904.

† *Finanz Chronik*, January 30, 1904.

coal mines in 1903 is estimated \* at 18,300,000 tons, of which 58 per cent. was used in the country and 42 per cent. exported.

**Coal-mining in Hungary.**—A detailed account has been published † of the development of the Saljo-Tarjan Coal Co. in Hungary. In 1867 the production was 35,000 tons; in 1903 it was 15,760,000 tons. In 1868 the number of workmen was 500; at the present time it amounts to 8000. The Hungarian collieries have been described in detail by A. von Kaleczinsky.‡

**Mineral Statistics of Bosnia and Herzegovina.**—Official statistics show that in the year 1903 there were produced in Bosnia and Herzegovina, in metric tons, iron ore 114,059, manganese ore 4537, chromium ore 147, lignite 467,962. The metallurgical production included pig iron 39,833, castings 1944, open-hearth steel ingots 17,678, wrought iron 16,626. The number of workpeople employed at the collieries amounted to 1682, at the iron ore mines to 339, and at the ironworks to 862. Altogether 7134 were employed in 1903 at all the mines and works, and of these 1 was killed by accident and 29 severely injured. §

#### IV.—BELGIUM.

**Mineral Statistics.**—The Belgian mineral statistics for 1902 have been issued by J. de Jaer. || The number of collieries in operation was 119 and the total output of coal was 22,877,470 metric tons. There were at the collieries 406 winding engines, 288 pumping engines, 395 ventilating engines, and 1669 motors of various kinds. The number of workmen was 134,889. In the metal mines the number of workmen was 356. The output included 14,440 tons of manganese ore. In the iron ore quarries 504 workmen were employed, and in other quarries 3802. The production of pig iron was 1,069,050 tons, or 40 per cent. more than in 1901.

The Belgian production ¶ during the second half of 1903 includes

\* *Montan Zeitung*, vol. xi. p. 63.

† *Ibid.*, p. 68.

‡ See Bibliography.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 277-279.

|| *Annales des Mines de Belgique*, vol. viii. pp. 1309-1344.

¶ *Moniteur des Intérêts Matériels*, vol. liv. p. 353.

11,968,520 tons of coal, 604,310 tons of pig iron, 191,990 tons of wrought iron, and 504,160 tons of steel ingots.

A review has been published\* of the Belgian coal trade during 1902. The output of each colliery is given, the Raunis de Charleroi collieries with 673,000 tons heading the list.

On April 1 there were in Belgium thirty-four blast-furnaces in operation. A list of the Belgian iron and steel works is given.†

Recent statistical reports ‡ comprise a list of the collieries in operation in Belgium, particulars of the mine timber used in Belgian collieries and the Belgian coal statistics for 1902.

The iron ore production amounted, in 1902, to 166,480 tons.§

**Steelworks.**—E. de Laveleye|| has written a series of articles on the history of the Belgian steel industry. The industry dates back to 1863, when the first steel rails were rolled by the Cockerill Company. He gives detailed accounts of the Cockerill works,¶ of the Ougrée works,\*\* and of the La Louvière steelworks, the works of the Thy-le-Château †† Company, of the Athus Company, and of the Angleur Company, and of the Sambre and Moselle steelworks.‡‡ He concludes with a comparison §§ of the Belgian conditions with those obtaining in Germany, Luxemburg, and France.

## V.—CANADA.

**Mineral Statistics.**—A preliminary summary of the mineral production of Canada in 1903 has been issued.||| The production of pig iron from Canadian ore was 42,052 tons, the total production of pig iron being 297,885 tons. The exports of iron ore amounted to 368,233 tons. The production of nickel was 12,505,510 lbs. The production of non-metallic minerals included 7,996,634 tons of coal, 544,132 tons of coke, 2317 tons of fire-clay, 738 tons of graphite, 135 tons of manganese ore, and 461,336 barrels of petroleum.

\* *Moniteur des Intérêts Matériels*, vol. liv. pp. 1-4.

† *Ibid.*, p. 1089.

‡ *Annales des Mines de Belgique*, vol. viii. pp. 1309-1344.

§ *Comité des Forges, Bulletin* No. 2338.

|| *Moniteur des Intérêts Matériels*, vol. liii. p. 3397.

¶ *Ibid.*, p. 3449.

\*\* *Ibid.*, p. 3529.

†† *Ibid.*, p. 3606.

‡‡ *Ibid.*, p. 3795.

§§ *Ibid.*, p. 3879.

||| *Board of Trade Journal*, vol. xlv. p. 13.

The American Iron and Steel Association \* has received direct from the manufacturers the statistics of the production of all kinds of pig iron in Canada in the year 1903. They show a decrease of 54,139 tons, or nearly 17 per cent., as compared with 1902, but an increase of 20,442 tons as compared with 1901. The total production in 1903 amounted to 265,418 tons, against 319,557 tons in 1902, and 244,976 tons in 1901. In the first half of 1903 the production was 132,930 tons and in the second half it was 132,488 tons, a falling off of only 442 tons. Of the total production in 1903, 247,905 tons were made with coke, and 17,513 tons with charcoal. Nearly one-half of the total production was basic pig iron, namely, 126,892 tons. Less than 1000 tons of Bessemer iron were made. Spiegeleisen and ferro-manganese have not been made since 1899. The unsold stocks of pig iron in Canada on 31st December 1903 amounted to 19,168 tons. On the same date Canada had 15 completed blast-furnaces, of which 9 were in blast and 6 were idle. Of this total, 11 were equipped to use coke for fuel and 4 to use charcoal. In addition, 3 coke furnaces and 1 charcoal furnace were being built or were partly erected on 31st December, but work on at least two of the furnaces had been suspended some time ago.

The future of the coal and coke supply of British Columbia is discussed by W. Blakemore.†

T. W. Gibson ‡ gives statistics showing the progress of mining and the manufacture of the products of mining in Ontario. The total output for 1903 was about 4·5 per cent. less than for 1902, but the special causes, such as the Sault situation, leading to this reduction, when carefully considered, show that progress has been most satisfactory.

**The Mining Industry of Newfoundland.**—According to J. P. Howley § the production of iron ore in Newfoundland in 1902 amounted to 728,721 tons, against 738,206 tons in the previous year. Newfoundland is not embraced in the Dominion of Canada.

## VI.—CHINA.

**The Mineral Resources of Indo-China.**—A recent report, || pre-

\* *Bulletin*, vol. xxxviii. p. 20.

† *Journal of the Canadian Mining Institute*, vol. vi. pp. 224-232.

‡ Paper read before the Canadian Mining Institute, March 1904.

§ *Report on the Mineral Resources. Geological Survey of Newfoundland*, 1903.

|| *Engineering and Mining Journal*, vol. lxxvi. p. 844.

pared under the direction of the local government of Indo-China, gives some interesting information regarding the status of the mining industry in that colony. In Tonkin, the most valuable resources under exploitation are the coal-mines at Quang-Yen, where a French company is operating with much success. The output of this company in 1902 was about 317,000 tons of coal. There is a smaller mine in the same locality operated by Chinese, and two small mines in the Province of Hainduong. In Annam the coal-mines of Nong-Son employ about 700 coolies, and turn out about 100 tons a day.

**Iron Foundries in Tonkin.**—The establishment of iron foundries on a large scale in Tonkin seems quite feasible. Rich deposits of iron ore have recently been discovered 36 miles from Hanoi. Not far from this place are the anthracite coal-mines of Hongay, which are now being successfully worked. This anthracite, mixed with coal from Japan or Yunnan would, it is said, produce coke eminently adapted for iron-smelting.\*

**Coal at Kiao-chou.**—The report of the German Navy on the development of the Kiao-chou region in 1903 contains an account of the coal deposits and the details of collieries at work in Schantung.†

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## VII.—FRANCE.

**Iron Trade Statistics.**—The metallurgical production of France during the year 1903, according to the provisional official statistics,‡ included 2,827,668 metric tons of pig iron, 595,931 tons of wrought iron, and 1,854,620 tons of steel ingots. Of the steel ingots, 1,172,984 tons were made in the Bessemer converter.

The definite statistics for 1902 have also been issued.§ The production included 2,404,974 tons of pig iron, 639,610 tons of wrought iron, and 1,245,806 tons of steel, consisting of 772,370 tons of Bessemer steel, 450,500 tons of open-hearth steel, 4737 tons of puddled steel, 1163 tons of cement steel, 12,986 tons of crucible steel, and 4050 tons of steel obtained by reheating scrap.

\* *Feuille de Renseignements*; *Board of Trade Journal*, vol. xlv. p. 82.

† *Glückauf*, vol. xl. pp. 379-380.

‡ *Journal Officiel*, March 5, 1904; *Comité des Forges*, *Bulletin* No. 2351.

§ *Comité des Forges*, *Bulletin* No. 2358.



The production\* of iron ore in France in 1902 amounted to 4,465,472 tons, and that in Algeria to 159,622 tons.

There were in operation in France on January 1, 1904, in the Eastern district, 66 blast-furnaces, in the North 12, and in the Centre, South, and West 31; the total is 109. Particulars of each company are given.†

The five works‡ showing the greatest daily outputs are the following :—

	Tons.
De Wendel . . . . .	700
Micheville . . . . .	675
Longwy . . . . .	650
Denain et Anzin . . . . .	540
Marine . . . . .	525

**Coal.**—According to statistics issued by the French Minister of Public Works, the production of coal in France in 1903 was 34,317,527 metric tons, the largest output recorded.§ The production of coal in the coal-fields of the Nord and Pas de Calais in 1903 was 22,938,100 tons. According to R. Pitaval|| the five collieries with the greatest output were :—

	Tons.
Lens . . . . .	3,228,715
Anzin . . . . .	3,136,480
Courrières . . . . .	2,225,730
Bruay . . . . .	2,101,322
Nœux et Vicoigne . . . . .	1,662,887

## VIII.—GERMANY.

**Mineral Statistics.**—The preliminary official statistics¶ show that the German Empire and Luxemburg in 1903 produced, in metric tons, coal 116,637,766, brown coal 45,674,309, and iron ore 21,230,639.

The definite official iron trade statistics of Germany and Luxemburg for 1902 have been published.\*\* There were 462 iron ore mines, employing 39,202 workmen, and producing a total of 17,963,591 tons valued at 3s. 8d. per ton. The production of pig iron was 8,529,899 tons.

\* *Comité des Forges, Bulletin* No. 2356.

† *Echo des Mines*, vol. xxxi. p. 54.

‡ *Moniteur des Intérêts Matériels*, vol. liv. pp. 56, 127.

§ *Journal of the Society of Arts*, vol. lli. p. 645.

|| *Echo des Mines*, vol. xxxi. p. 100.

¶ *Verein deutscher Eisen- und Stahl-Industrieller*, 1904, No. 6.

\*\* *Ibid.*, 1903, No. 18.

A statement has been published\* giving the output of every colliery in the Dortmund district in 1903. The coal production of the district amounted to 64,700,000 tons, and the total number of workmen employed was 243,963. There is also a supplement covering 150 pages, containing a full report of the debate on the mining estimates in the Prussian parliament.

During the five years from 1899 to 1903 the Rhenish brown coal industry has developed in a satisfactory manner.† The output, which in 1890 was only 661,000 tons, was 3,917,202 tons in 1899, and 5,926,214 tons in 1903. The briquette production was 924,704 tons in 1899, and 1,469,139 tons in 1903. The number of presses increased from 118 in 1899 to 185 in 1903.

Particulars have been published‡ of the wages paid to miners in Prussia in 1902. There were altogether 480,336 miners employed, of whom 394,180 were engaged in coal mining, 33,676 in lignite mining, 32,177 in ore mining, 14,700 in copper-shale mining, and 5603 in salt mining. The total amount paid in wages was £24,149,530. The wages per shift varied from 3s. 10d. in the Dortmund district to 2s. 5d. in the Rhenish ore mines. The output of coal per miner tends to decrease. In 1888 it was 300 tons, while in 1902 it was 244 tons. The number of shifts worked varied from 277 in the Upper Silesian collieries to 305 in the Mansfeld copper mines.

**Iron Trade Statistics.**—The production of pig iron in Germany and Luxemburg in 1903 amounted to 10,085,634 tons as compared with 8,402,660 tons in 1902.§

A series of comparative tables are published|| showing the iron trade statistics of Germany, including Luxemburg, for the years 1900, 1901, and 1902, and other similar details are also given for each of the years from 1894 to the last-named year.

Attention is drawn¶ to the progress which has been made by the iron trade of Germany in 1903. The production of pig iron in Germany in 1900 amounted to 8,520,541 metric tons. In 1901 there was great depression, the production falling to 7,880,087 tons. In 1902, however, things had changed again, and the output increased to 8,402,660 tons,

\* *Glückauf*, vol. xl. p. 236.

† *Ibid.*, p. 376.

‡ *Montan Zeitung*, vol. x. pp. 459-461.

§ *Verein deutscher Eisen- und Stahl-Industrieller*, 1904, Nos. 1 and 2.

|| *Stahl und Eisen*, vol. xxiv. pp. 104-107.

¶ *Ibid.*, vol. xxiii. pp. 1305-1306.

this increase continuing in 1903 to such an extent that the production during the ten first months of the year was almost as much as in the whole of 1902. It is estimated that the output for the year will exceed ten million tons, or over 21 per cent. increase as compared with 1902.

The production of steel has made similar progress, an increase of more than 20 per cent. being anticipated for the whole year, the estimate for the year's outturn showing over nine million tons.

Comparison is made between the production of pig iron in Germany and in the United Kingdom, and it is shown that the German output exceeded the British by 29.5 per cent. in 1900, by 25.8 per cent. in 1901, and by as much as 56 per cent. in 1902. After comparative statistics dealing with the production of the United States, others are given relating to German iron trade exports, it being pointed out that it is recognised that if the German iron-makers are to be able to deal with their enormous output, foreign markets must be largely utilised. It is added that this rapid increase is due to the trust system. The pig iron syndicate has recently been renewed for another three years, and similar syndicates deal with semi-manufactures, rails, beams, and sleepers. Proposals have for some time been under consideration for the combination into one trust of all the steelworks in Germany, and it was formed on the last day of February 1904. Particulars have been published.\*

Steel was made in Germany in 1903 at 101 works. There has been a rapid increase in the outturn in recent years.† The total was made up as follows:—

	Acid Method.	Basic Method.	Totals.
	Metric Tons.	Metric Tons.	Metric Tons.
Bessemer ingots . . . . .	435,327	5,473,195	5,908,522
Open-hearth ingots . . . . .	132,693	2,628,544	2,761,237
Steel castings . . . . .	45,379	86,377	131,756
Totals . . . . .	613,399	8,188,116	8,801,515

The above statistics for 1903 are those prepared for the *Verein deutscher Eisen- und Stahl-Industrieller*, and include estimated figures only of the smaller works.

A brief historical account is published ‡ of the rise and progress of the Westphalian Iron Industry.

\* *Stahl und Eisen*, vol. xxiv. pp. 329-331.

† *Ibid.*, p. 416.

‡ *Ibid.*, vol. xxiii. pp. 1245-1247.

H. Wedding \* discusses the influence which has been exerted by the German patent regulations on the iron industry of Upper Silesia. Lists of patents are given, and the subject is discussed generally.

**Mineral Statistics of Luxemburg.**—In the Grand Duchy of Luxemburg there were 76 iron mines in operation in 1902. There were 8 ironworks with 27 blast-furnaces in operation, 9 foundries, and 3 steelworks. The number of men employed was 5197 at the iron mines, 3358 at the blast-furnaces, and 1317 at the steelworks. The output comprised 5,130,069 tons of iron ore and 1,080,305 tons of pig iron. †

**Mineral Statistics of Alsace-Lorraine.**—In 1903 there were in operation in Alsace-Lorraine 57 iron ore mines, 3 collieries, 7 bitumen mines, 18 salt mines or works, 43 blast-furnaces, 46 iron foundries, 7 wrought iron works, and 7 steelworks. The production of these works included, in tons, iron ore 10,683,042, coal 1,583,365, petroleum 20,947, asphalt 5190, pig iron 1,973,985, wrought iron 51,731, steel 968,084, and iron castings 62,461. ‡

**Canal Transport.**—One of the most important possible improvements towards reduction in internal freight charges on ore and coke in Germany is held to lie in the canalisation of the rivers. Further details are now given in this connection that refer to the Moselle and the Saar. An available 47,000 horse-power is estimated as obtainable by the use of turbines from the Moselle. §

Details are given, ¶ with 4 coloured maps, of the new canal schemes before the Prussian parliament. The estimates include £9,852,500 for a ship canal from the Rhine to Hanover, £2,150,000 for a ship canal from Berlin to Stettin, £1,058,750 for improving the canal between the Oder and Weichsel, and £947,500 for the canalisation of the Oder to Breslau, making a total of £14,013,700.

**Metallurgical Education.**—An interesting address delivered by Lengemann on the historical development and present condition of mining education in Germany has been reprinted. ¶

\* *Stahl und Eisen*, vol. xxiv. pp. 139-143.

† *Comité des Forges, Bulletin* No. 2367.

‡ *Glückauf*, vol. xl. p. 464.

§ *Stahl und Eisen*, vol. xxiii. pp. 1244-1245.

¶ *Glückauf*, vol. xl. pp. 445-452.

¶ *Ibid.*, pp. 192-200.

The question of the advanced teaching of iron metallurgy in Prussia is dealt with by J. Hörhäger.\*

A. Ledebur† points out that the Mining Academy at Freiberg in Saxony is the most ancient of the existing Technical High Schools. It was founded in 1766. The subjects taught comprised metallurgical chemistry, which included metallurgy, mathematics, mechanics, mining, mine surveying, and assaying. Minerals were exhibited, but mineralogy in the true sense of the word was not taught. As a science it was, however, still in its earliest infancy in those days.

Details are published‡ with reference to the arrangements for the teaching of the metallurgy of iron at the Technical High School at Aix-la-Chapelle. It is desired to extend considerably the scope of the tuition now given and to increase the available accommodation for this purpose.

At Munich a museum of masterpieces of science and technology is being formed. The Imperial Government has voted a yearly subvention of £2500, and the same sum will be given by the Bavarian Government. The city of Munich has voted an annual grant of £750, and the Society of German Engineers £250. Numerous substantial contributions have been promised by individuals. Subscribers of 9s. annually are entitled to free admission to the museum and to copies of the annual reports.

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## IX.—HOLLAND.

**Coal.**—According to the official statistics§ in 1902 Holland produced 399,133 tons of coal, or 86,416 tons more than in 1901. This output was obtained by four collieries. There were 1486 persons employed, of which 1159 worked underground.

A. Van Raemdonck gives a translation|| of two important measures recently passed in Holland affecting the existing mining regulations.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 67-70.

† *Stahl und Eisen*, vol. xxiii. pp. 1114-1115.

‡ *Ibid.*, pp. 1257-1268.

§ *Ibid.*, p. 1421.

|| *Annales des Mines de Belgique*, vol. viii. pp. 1279-1307.

## X.—INDIA.

**Mineral Statistics.**—The following particulars relating to the mineral production of British India in 1902 are extracted from a return compiled under the direction of R. E. Enthoven.\*

The production of iron is as yet in its infancy, the ore being worked for the most part only in the Raniganj district of Bengal, where it occurs in close proximity to the coal-fields. The production in 1902 only amounted to 80,869 tons, of which 76,056 tons were produced in Raniganj. The adequate utilisation of the iron ores of Bengal and other parts of India involves the application of very large capital. The cost of fuel is also a difficulty in places where coal-fields are remote. Efforts are being made in Western India to overcome these difficulties, and to start experimental workings of certain rich iron ores in the Central Provinces.

The coal industry is expanding so rapidly from year to year that a statement of the average production over a series of years would not convey a true idea of the conditions. The output has increased from 3,540,000 tons in 1895 to 7,424,500 tons in 1902. Coal is found of varying quality over a very extensive area of the Indian region. At present the principal mines are located in the Raniganj, Jherria, and Giridih coal-fields in Bengal, at Singareni in the Nizam's Territory, at Makum in the Lakhimpur district in Upper Assam, at Mohpani and Warora in the Central Provinces, and at Umaria in the Central Indian Agency.

Indian coal is now extensively employed for the railways, coasting and river steamers, mills and factories; but the conditions of transport are not yet sufficiently developed, though they are being greatly improved, to permit of the exclusive use of Indian coal for industrial purposes. The quantity of Indian coal used in India is therefore supplemented by an importation which has averaged 267,000 tons annually in the last five years.

The petroleum production, which is confined to Burma and Assam, amounted to nearly 57 million gallons in 1902, more than 54 million gallons being of Burmese production. Although the production has expanded very largely, it is still insufficient for the requirements of the Indian market, which are met by the importation of some 81 million gallons from the United States and Russia.

In the State of Travancore there are three mines from which graphite

\* *Board of Trade Journal*, vol. xliii. p. 346-348.

was extracted in 1902 to the extent of 4575 tons. No information has been given of the quality of the graphite. It is doubtless exported, but no particulars of the trade have been furnished, nor are the capabilities of the mines known. A trifling quantity, 9 cwt., of plumbago was extracted in 1902 from the Ruby Mines in Burma.

**Mineral Statistics of Mysore.**—The Report of the Chief Inspector of Mines \* states that in 1902 there were produced 9600 cwt. of iron ore, 1720 cwt. of iron, and 10 cwt. of steel.

## XI.—JAPAN.

**Mineral Statistics.**—The mineral production of Japan in 1901 included 8,945,938 tons of coal, 55,171 tons of pig iron, and 16,298 tons of manganese ore.†

## XII.—MEXICO.

**Mineral Industry.**—According to E. Ludlow,‡ the total production of coal in Mexico in 1902 was 759,654 metric tons. This coal was produced by three companies: The Coahuila Coal & Coke Company, reporting 282,000 metric tons; the Fuente Coal Company, 82,600 tons; and the Mexican Coal & Coke Company, 395,054 tons. The production of coke during the year was 71,710 metric tons. The Coahuila Coal Company made 18,700 tons; this company owns 120 ovens, of which 60 were in operation during the year. The Mexican Coal & Coke Company produced 53,010 tons of coke; it has 226 ovens, of which 200 were in operation at the close of the year. A brief review of the coal-fields is given.

It is reported§ that an English company has secured a lease of the iron ore deposits of the Isthmus of Tehuantepec, Mexico. It is intended to export the ore by way of Coatzacoalcos.

\* *Report of the Chief Inspector of Mines, Mysore Geological Department, Bangalore, 1903.*

† Official Return furnished by the Mining Bureau at Tokyo to the Home Office.

‡ Abstract from article in *Mineral Resources of the United States for 1902*. From advance proofs.

§ *Iron Age*, December 17, 1903, p. 7.

## XIII.—NORWAY.

**Mineral Statistics.**—The mineral statistics of Norway in 1901 have been published \* by the Central Statistical Bureau of Christiania. The mineral products included, in tons, nickel ore, 2018; iron ore, 42,252; chrome ore, 85; and molybdenum glance, 4.

In 1902 the Norwegian exports included 48,769 tons of iron ore, 115 tons of nickel ore, 14 tons of molybdenum ore, and 122 tons of chrome ore.†

## XIV.—PORTUGAL.

**Mineral Statistics.**—According to the official statistics,‡ Portugal in 1902 produced 19,914 tons of iron ore, 234 tons of tungsten ore, 11,000 tons of anthracite, and 5792 tons of lignite.

## XV.—ROUMANIA.

**Petroleum.**—Jacques Kanitz§ gives a review of the Roumanian petroleum industry during 1903. The production is estimated at 390,000 tons or 26 per cent. more than in 1902. The Steaua Romana Company produced 43 per cent. of the total, the Telega Oil Co., Ltd., 11 per cent., and the Internationale Rumeensche Co. 9 per cent. The exports were 126,264 tons, of which 37,085 tons went to England.

Detailed statistics of the Roumanian petroleum industry in 1903 are also given by J. Kanitz.||

Details are given¶ of the production and consumption of petroleum in Roumania in 1903 by months and districts.

An article on the Roumanian petroleum fields has appeared.\*\* It is stated that the cost of a well sunk by hand to a depth of 650 feet is £700. The cost of a borehole put down by machinery is £2300 to £3000. For boring to a depth of 1000 feet three months are required. Wages costs 180 francs daily, namely, 5 francs a day for skilled workmen, and 200 to 250 francs a month for boremasters.

\* *Berg- und Hüttenmännische Zeitung*, vol. lxii. p. 610.

† *The Quarry*, vol. ix. p. 155.

‡ *Mines and Quarries: General Report and Statistics*, Part IV. p. 438. London, 1904.

§ *Moniteur du Pétrole Roumain*, vol. v. pp. 39–46.

|| *Allgemeine österreichische Chemiker und Techniker Zeitung*, vol. xxii. No. 3.

¶ *Ibid.*, No. 4.

\*\* *Finanz-Chronik*, November 14, 1903.



The production of petroleum in Roumania in 1903 amounted to 384,303 tons. A complete list of the wells in operation is given.\*

## XVI.—RUSSIA.

**Iron Trade Statistics.**—The practice and conditions of the iron industry in the three leading iron-producing districts of South Russia, the Ural, and Poland are reviewed by Holz.† The ores smelted, the additions, fuel, and labour conditions are fully dealt with.

T. Naske‡ and E. A. B. Taube describe the condition of the iron and coal industry of Russia at the close of the nineteenth century. In 1900 this industry of Russia reached its maximum. Its rapid rise during the last decade of the nineteenth century has attracted general attention. It was chiefly the South of Russia which contributed to this progress. A reaction followed, due partly to this very rapid increase in the production and also to the stagnation which then existed in the condition of the iron trade of Europe, and the authors now quote from a recent publication dealing with this period in Russia.§

In 1900 the output of iron ore amounted to 6,114,520 tons, 57,752 workpeople being employed. The production was thus about 106 tons per man and per year. This was raised as follows in the districts shown :—

District.	Workpeople.	Mines.	Production.
			Metric Tons.
Ural . . . . .	30,512	684	1,661,290
Moscow . . . . .	7,549	93	387,147
Poland and North-West Russia	6,574	125	484,283
South, South - West, and } South-East Russia . }	10,853	...	3,445,171
Siberia . . . . .	49	4	9,484
North Russia . . . . .	2,126	50	34,303
Caucasus . . . . .	...	...	3,535
Finland . . . . .	79	169	89,306
Totals . . . . .	57,752	...	6,114,519

As the production in the preceding year was only 5,893,252 tons, a very considerable increase had taken place in the output during the year.

\* *Finanz-Chronik*, vol. ix. p. 146.

† *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1903, pp. 255-270.

‡ *Stahl und Eisen*, vol. xxiii. pp. 1281-1284, 1318-1326.

§ *Sbornik statisticheskikh Svyedyeni o Gornozavodskoi Promyshlennosti Rossii v. 1900 godu*.

Dealing next with manganese ores, the authors state that in 1900 there were in Russia 372 active manganese ore mines which yielded 803,213 tons, an increase of 143,107 tons as compared with the output in the preceding year, or as much as 21 per cent:—

District.	Production. Metric Tons.
Kutais . . . . .	662,010
Perm . . . . .	582
Orenburg . . . . .	2,651
Ekaterinoslav . . . . .	137,676
Semipalatinsk . . . . .	294
Total . . . . .	803,213

It is important, however, to note that while the production of manganese ore has rapidly increased, its contents of manganese has steadily decreased, and while this had already been observed in 1900, the year under discussion, its effect has been very marked at the Russian works in 1903. As regards the output of manganese ore, Russia occupies the premier position, the United States taking the second place and Spain the third.

Dealing next with chromium ore, the authors state that in 1900 this was mined in the governments of Perm and Orenburg. From 35 mines 18,256 tons of ore was mined, or a diminution of 913 tons as compared with the production in 1899. The total world's production of chrome ore was 49,200 tons.

The production of pig iron is next passed in review. At 182 works there was made, in 1900, 2,937,365 tons of pig iron. Of this 57 per cent. was made with "mineral fuels," 31 per cent. with charcoal, and 12 per cent. with mixed fuel. The works were as follows:—

District.	Works.	Active Blast-Furnaces.		Total.
		With Cold Blast.	With Hot Blast.	
Ural . . . . .	74	15	123	138
Moscow . . . . .	37	3	52	55
Poland and Vilna . . . . .	23	3	30	33
South, South-West, and } South-East Russia . . . }	20	2	43	45
North Russia . . . . .	10	6	5	11
Siberia . . . . .	3	2	2	4
Finland . . . . .	15	1	15	16
Totals . . . . .	182	32	270	302

Further details are given as to these and the periods during which they were in blast. They smelted altogether 5,258,267 tons of iron ore, 329,759 tons of slags, cinders, &c. The yield of pig iron was 50 per cent. of the charge. The fuel consumed per ton of pig iron was 1.25 ton of mineral fuel or 3.33 tons of charcoal.

In 1901 and 1902 trade conditions were so unsatisfactory that many furnaces were put out of blast, especially in South Russia. The authors give statistics showing the distribution of the production among the various governments, and then give a list of 42 ironworks stating where they are situated, the number of blast-furnaces which each possesses, their production of pig iron, and what kind of fuel is employed. The largest is the Yusova works, with 7 blast-furnaces and an outturn of 272,452 tons of pig iron, in the government of Ekaterinoslav, and the smallest is the Ylevski works in Nijni Novgorod, which, using charcoal, made 12,371 tons in 1900 in two blast-furnaces. South Russia showed the greatest outturn, and next to this came the Urals.

The following is another table also given :—

Year.	Blast-Furnaces.			Pig Iron produced using		
	Cold Blast.	Hot Blast.	Total.	Charcoal.	Mineral Fuel.	Mixed Fuel.
				Metric Tons.	Metric Tons.	Metric Tons.
1891 . .	70	152	222	667,913	333,166	4,893
1892 . .	65	156	221	658,022	376,151	38,907
1893 . .	54	168	222	680,065	437,823	32,417
1894 . .	51	183	234	747,137	560,025	26,930
1895 . .	48	194	242	693,191	695,806	65,113
1896 . .	47	202	249	738,411	813,479	70,901
1897 . .	52	212	264	849,258	962,501	70,664
1898 . .	50	224	274	835,127	1,274,466	134,433
1899 . .	54	239	293	866,515	1,709,859	135,683
1900 . .	32	270	302	905,429	1,680,284	361,652

In about ten years, therefore, the outturn of pig iron in Russia was approximately trebled. Other statistical details are also given.

The production of weld iron is next dealt with, statistics for the various governments being given. In 1892 it was 481,619 metric tons, and in 1901, 489,961 tons. The production of ingot iron and steel is also considered. Unlike the outturn of weld iron, that of ingot iron and steel has increased enormously. In 1891 it amounted, for instance, to but 434,006 tons, while in 1900 it was as much as 2,218,638 tons. The authors give a further series of tables relating to this, and then

consider the production of castings and finished products, which has also made progress.

The total number of workpeople at all the ironworks of Russia in 1900 was 331,778, rather more than half of whom were employed in the Ural. In 1901 and 1902, however, the depression in the Russian iron trade has caused a great reduction in the number of the operatives. Thus while the number employed at the South Russian works in 1900 was 53,413, in 1901 it had decreased to 49,863, and in 1902 to but 43,212.

Coal and coke are next considered, the outputs of the various districts being given and also the number of men employed. The way the coal raised was consumed is also shown. Imports and exports are also tabulated and considered.

The exportation of iron ore from the south of Russia is discussed.\* The total amount of ore transported by railway in 1903 was 172,823,850 poods. Timé of St. Petersburg regards the export of Krivoi-Rog as detrimental to the development of the South Russian iron trade.

The production of pig iron in Russia (exclusive of Finland) in 1903 amounted to 143,000,000 poods, as compared with 156,500,000 poods in 1902.†

A report on the iron and coal industries of South Russia has been issued by Henin,‡ the Belgian Consul-General at Ekaterinoslav; and an article on the Russian iron industry has appeared.§

It is reported|| that South Russia produced 83,178,556 poods of pig iron in 1903. There were 32 blast-furnaces in operation. In 1903 the Donetsk coal-field produced 646,890,000 poods of coal, and 81,200,000 poods of anthracite.

An article on mining in Russia, based on a report by the Austrian Consul at Tiflis, has been published.¶ In Transcaucasia, the petroleum industry has been developed in a remarkable manner, and the manganese industry is of considerable importance. On January 1, 1903, there were in the Baku district 1402 productive boreholes with an average depth of 392 metres. Of these boreholes 31 were over 554 metres in depth. The production of manganese ore in 1902 amounted to 34,943,315 poods.

\* *Moniteur des Intérêts Matériels*, vol. liv. p. 980.

† *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 159.

‡ *Board of Trade Journal*, vol. xlv. p. 402.

§ *Moniteur des Intérêts Matériels*, vol. liv. pp. 1303-1304.

|| *Ibid.*, pp. 1143.

¶ *Montan Zeitung*, vol. xi. p. 33.

Statistics are given \* showing that in the year ending September 1, 1903, the Russian coal trade output was 613 million poods of coal and 77 million poods of anthracite, or 7 per cent. more than in the preceding year. The number of miners employed was 67,669. The production of pig iron was 76,075,000 poods, or 15 per cent. less than in the preceding year. There were 14 works and 26 blast-furnaces in operation, and 36,272 workmen were employed.

**Petroleum.**—At a congress of representatives† of the petroleum industry the methods of obviating the disastrous conflagrations were discussed. The following figures show the increasing frequency of these fires :—

Years.	No. of Fires.	Wells Burned.	Loss in Roubles.
1897 . . . . .	13	60	299,000
1898 . . . . .	9	48	526,800
1899 . . . . .	13	63	350,000
1900 . . . . .	27	335	2,658,000
1901 . . . . .	22	250	1,430,000
1902 . . . . .	28	280	1,385,850
1903 (to September) .	25	272	3,336,400

H. Winkel ‡ notes that the production of petroleum in Russia from 1881 to 1902 inclusive was 6588 million poods or, in volume, 120 million cubic metres. The Baku district alone has yielded 95 per cent. of this total, or 114 million cubic metres of crude petroleum. It is probable that in the period under consideration there has been extracted 150 million cubic metres of liquid that has been replaced by nothing. The oil-bearing area is comparatively small, only 10,450,000 square metres, so that there must be a vacant space 14·35 metres in height. How is it that no subsidence of the surface has taken place?

## XVII.—SOUTH AMERICA.

**Mineral Resources.**—C. Vattier,§ in describing the present position of the metallurgical industries of South America, states that vanadium ore has now begun to be mined on an important scale in Peru. He also

\* *Moniteur des Intérêts Matériels*, vol. liii. p. 3481.

† *Ibid.*, vol. liv. p. 207.

‡ *Moniteur des Intérêts Pétrolifères Roumains*, vol. iv. pp. 624–625.

§ *Bulletin de la Société Scientifique Industrielle de Marseille*, vol. xxxi. pp. 13–52.

refers to the abundance of magnetite in the Honduras, where the mineral is also being exploited. Iron exists in workable quantities in Porto Rico, and the vast deposits of manganese in Cuba still await development. Water-power abounds largely in these latter islands which might be made available for the exploitation.

An article on the mineral resources of Peru has appeared.\* The deposits of iron ore, coal, and petroleum are enumerated. The working of iron ore is at present neglected, although rich deposits occur in Tambo-Grande in Piura, and in the provinces of Calca and Larex.

I. Bolstad † discusses the iron industry of Brazil.

## XVIII.—SPAIN.

**Mineral Statistics.**—The production of iron ore in Spain in 1903 amounted to 8,478,600 tons, against 7,904,555 tons in 1902. The exports were 7,692,214 tons in 1903 and 7,560,020 tons in 1902. The production of pig iron in 1903 was 380,284 tons, that of Bessemer steel 105,263 tons, that of open-hearth steel 94,379 tons, and that of wrought iron 53,288 tons. ‡

The production of iron ore in the province of Biscay in 1902 was 5,059,405 tons as compared with 4,969,451 tons in 1901.§

The Spanish mineral production in 1902 included, in metric tons, asphalt 5694, iron ore 7,836,063, coal 2,621,171, lignite 55,712, manganese ore 51,762. ||

A. Contreras ¶ gives details of the production of coal in Spain in 1903. The total output of coal is stated to be 2,700,835 tons. The production of anthracite was 176,146 tons, and that of lignite 97,278 tons.

During the year 1903 little progress was made in the coal trade of Spain. The exports were only 2626 tons against 9676 tons in 1902, whilst the imports were 52,738 tons less than in 1902.\*\*

A review of the Spanish coal trade in 1903 has been published.††

\* *Finanz Chronik*, vol. ix. p. 381.

† *Bihang till Jernkontorets Annaler*, 1903, pp. 230-240.

‡ *Revista Minera*, vol. lv. pp. 165-168.

§ *Gaceta Minera de Cataluña*, vol. iv. p. 32.

|| *Galicia Minera*, vol. ii. No. 34.

¶ *Revista Minera*, vol. lv. pp. 131-133.

\*\* *Gaceta Minera de Cataluña*, vol. iv. p. 81.

†† *Revista Minera*, vol. lv. pp. 1-3.

The exports of manganese ore from the province of Huelva during the year 1903 amounted to 59,035 tons.\*

The Spanish imports in 1903 included, in metric tons, coal 2,075,429, coke 180,536, pig iron 2173, wrought iron 5371, and steel rails 14,258. The exports included, in metric tons, iron ore 7,692,714, pig iron 45,037.†

## XIX.—SWEDEN.

**Iron Trade Statistics.**—The exports of iron ore from Sweden in 1903 amounted to 2,827,552 tons as compared with 1,719,294 tons in 1902. The Luossavaara-Kiirunavaara Company has informed the State railway authorities that the probable quantity of iron ore to be conveyed over the Gellivare line in 1904 will amount to 1,200,000 tons. The other exports from Sweden in 1903 include: 70,100 tons of pig iron, 8900 of scrap, 8500 of ingots, 23,000 of blooms, 180,900 of bar iron, 2900 of iron bars, 4800 of wire rod, 2000 of sheets, 8500 of pipes, 1700 of wire, and 4300 of nails. This total output was 7100 tons in excess of the output in 1902.

The production, details of which have been kindly supplied by R. Åkerman, Director-General of the Swedish Board of Trade, was as follows in 1903 :—

Iron ores . . . . .	3,677,841 metric tons
Pig iron made with charcoal . . . . .	506,825 "
Blooms produced from pig iron in charcoal hearths . . . . .	192,842 "
Bessemer ingots and castings . . . . .	84,229 "
Open-hearth ingots and castings . . . . .	232,878 "
Crucible ingots and castings . . . . .	1,105 "
Blister steel . . . . .	685 "
Bar iron and steel . . . . .	178,538 "
Nail and wire rods, band iron and steel . . . . .	106,628 "
Otherwise shaped iron and steel in bars . . . . .	7,615 "
Plates (not including sheets) . . . . .	14,027 "
Tube-blocks, hollow blooms and billets . . . . .	24,959 "
Coal . . . . .	320,390 "
Number of blast-furnaces in blast . . . . .	114
Average daily product per furnace . . . . .	14.58 metric tons
Average time per furnace in blast . . . . .	256 days

\* *Revista Minera*, vol. lv. p. 41.

† *Ibid.*, p. 81.

During the period April–December 1903 there were in operation 98 blast-furnaces, 292 fineries, 19 converters, and 46 open-hearthls.\*

The annual report of the Luossavaara-Kiirunavaara Company for 1903† shows that during the year 848,183 tons of iron ore were produced at Kiruna, 960,471 tons were transported to Narvik, 791,607 tons were shipped at Narvik, and 15,765 tons at Luleå.

The Gellivare ore production in 1903 was 930,858 tons, and 931,794 tons were transported to Luleå.‡

An article has been published§ on the Scandinavian trade in mine-timber. The trade is very extensive, most of the timber being shipped as long or short props to Great Britain. The former are usually 15 feet long, and the latter 2½ to 8 feet long. In 1901 Norway shipped 242,000 cubic metres. Finland in 1903 exported 1,300,000 cubic metres, and Sweden in 1902 exported 1,500,000 cubic metres.

## XX.—UNITED STATES.

**Iron Trade Statistics.**—The American Iron and Steel Association has published the complete statistics of pig iron production in the United States in 1903. || The total output of the blast-furnaces in 1903 was 18,009,252 tons of pig iron, an increase of 187,945 tons, or 1·1 per cent. over the previous year. Of the iron made last year, 9,707,367 tons were turned out in the first half of the year, and 8,301,885 tons in the second half.

	1903.	
	Tons.	Per Cent.
Foundry and forge . . .	5,785,957	32·1
Bessemer pig . . . .	9,989,908	55·5
Basic pig . . . . .	2,040,726	11·3
Spiegel and ferro . . .	192,661	1·1
Total . . . . .	18,009,252	100·0

\* *Affärsvärlden*, vol. iv. p. 169.

† *Ibid.*, p. 603.

‡ *Ibid.*, p. 586.

§ *Ibid.*, vol. iv. pp. 383–385.

|| *Bulletin of the American Iron and Steel Association*, vol. xxxviii. pp. 12, 36.



There is a slight discrepancy in this classification, and some iron reported by the furnaces under foundry and forge is used in making steel of various grades. This is due to the furnace reports, however, and not to the association.

Six States last year made over half a million tons each. In the order of their output these States were: Pennsylvania, 8,211,500; Ohio, 3,287,434; Illinois, 1,692,375; Alabama, 1,561,398; New York, 552,917; Virginia, 544,034 tons. Pennsylvania alone made 45·6 per cent. of all the pig iron.

Classified according to grade the production of pig iron was as follows : \*—

	1903. Tons.
Bessemer and low phosphorus pig iron . . . . .	9,989,908
Basic pig iron made with mineral fuel . . . . .	2,040,726
Forge pig iron . . . . .	783,016
Foundry and high silicon pig iron . . . . .	4,409,023
Malleable Bessemer pig iron . . . . .	473,781
White and mottled and other grades . . . . .	120,137
Spiegeleisen . . . . .	156,700
Ferro-manganese . . . . .	35,961
<b>Total . . . . .</b>	<b>18,009,252</b>

The total production of Bessemer steel ingots and castings † in 1903 was 8,577,228 tons (of 2240 lbs.) against 9,138,363 tons in 1902, a decrease of 561,135 tons, or over 6 per cent. The production of 1902 was much the largest hitherto recorded. The production of all kinds of Bessemer steel rails by the producers of Bessemer steel ingots in 1903 was 2,813,583 tons, against a similar production in 1902 of 2,876,293 tons. The production in 1903 was 62,710 tons less than in 1902, when the maximum production was reached.

In the following table the production of rails, weighing 45 lbs. and less than 85 lbs. to the yard, is separated from those weighing less than 45 lbs. and over 85 lbs. to the yard. Bessemer rails made from purchased ingots or from re-rolled rails by companies which do not manufacture Bessemer ingots are not included :—

\* *Iron Age*, March 17, 1904, p. 23.

† *Bulletin of the American Iron and Steel Association*, vol. xxxviii. p. 52.

States.	Under 45 lbs.	45 lbs. and less than 85.	85 lbs. and over.	Total.
	Tons.	Tons.	Tons.	Tons.
Pennsylvania . . . .	97,697	571,271	456,578	1,125,546
Other States . . . .	79,964	927,407	680,666	1,688,037
Total for 1903 . . . .	177,661	1,498,678	1,137,244	2,813,583
„ 1902 . . . .	227,068	2,004,063	645,162	2,876,293
„ 1901 . . . .	140,214	2,202,237	493,822	2,836,273

There was, it will be observed, a large increase in 1903 in the production of Bessemer steel rails weighing 85 lbs. and over, as compared with 1902, and a considerable decrease in rails weighing 45 lbs. and over and less than 85 lbs. The production in 1903 of rails weighing less than 45 lbs. also show a decrease.

The American iron industry is discussed by P. Lazar.\*

O. Simmersbach † discusses the growth of the American iron and coal trades.

Particulars of the iron industry of the United States in 1903 are given by P. Pietrusky. ‡

Schwabe§ deals with the abundant supply of raw materials in the United States. He shows that of the world's total production the United States produce 31·9 per cent. of the coal and 34·7 per cent. of the pig iron.

**Mineral Statistics.**—According to the returns of the Twelfth Census, the mineral production of the United States in 1902 represented a value of 884,040,869 dollars as compared with 444,012,298 dollars in 1889. During the period 1889–1902 the value of the iron ore production increased from 33,351,978 dollars to 65,465,321 dollars. ||

**Production of Iron Ores.**—According to J. Birkinbine ¶ the production of iron ore in the United States in 1902 amounted to 35,554,135 tons. Of this total 30,532,149 tons consisted of red

\* *Bányászati és Kohászati Lapok*, vol. xxxvii. pp. 3–11.

† *Glückauf*, vol. xl. pp. 14–18.

‡ *Berg- und Hüttenmännische Zeitung*, vol. lxxiii. pp. 193–196.

§ *Glückauf*, vol. xxxix. pp. 1085–1086.

|| *Iron Age*, May 12, 1904, p. 20.

¶ *United States Geological Survey; Mineral Resources*, 1902, pp. 41–73, Washington, 1904.

hæmatite, 3,305,484 tons of brown hæmatite, 1,688,860 tons of magnetite, and 27,642 tons of carbonate.

J. Birkinbine\* has prepared a map showing the distribution of the iron ores mined in the Lake Superior region in 1902. The relative quantities are indicated by the number of lines, each full line representing a million tons. The volume which passed through Lake Huron was 22,600,000 tons.

The shipments by water and rail for the Lake Superior districts are given † as follows :—

	1903.	Number of Mines.
	Tons.	
Marquette . . . .	3,040,245	22
Menominee . . . .	3,741,284	33
Gogebic . . . .	2,912,912	28
Vermilion . . . .	1,676,699	5
Mesabi . . . .	12,892,542	53
Miscellaneous . . . .	17,913	...
Total . . . .	24,281,595	141

To this total must be added 203,419 tons from the Helen mine in the Michipicoten range.

**Production of Manganese Ore.**—According to J. Birkinbine,‡ the production of manganese ore in the United States in 1902 amounted to 16,477 tons, and that of manganiferous iron ores to 901,214 tons.

**Steel Hardening Metals.**—The following is given§ from the preliminary report of the United States Twelfth Census :—Under the head of steel hardening metals are included metals used or experimented with in the hardening of steel, although some of them are used more generally for other purposes. The metals included in this class are nickel, chromium, tungsten, molybdenum, titanium, uranium, and vanadium. There is still another metal that naturally comes under this

\* *United States Geological Survey*, February 1, 1904.

† *Iron Trade Review*, February 18, 1904, p. 60, and Supplement.

‡ *United States Geological Survey, Mineral Resources*, 1902, pp. 133-161, Washington, 1904.

§ *Iron Age*, May 12, 1904, p. 21.

head, namely, manganese; but on account of its comparatively large production it is treated separately. The statistics for these metals during 1902 state the number of mines at twelve, with a product of 4444 tons (of 2000 lbs.), valued at 83,717 dollars. Of the twelve mines, four were producing tungsten ores; three, uranium and vanadium ores; one each, chrome ore, molybdenum ore, and rutile; and two, nickel and cobalt ores. Nickel and cobalt ores were concentrated into a matte. Tungsten ores were concentrated more or less. The value of the other ores is the value as mined. One chrome ore mine in California, four tungsten mines in Arizona, Colorado, Nevada, and Wisconsin, and two uranium and vanadium mines in Colorado were reported idle during 1902.

Inquiries regarding productive tungsten mines in the United States show\* that tungsten ores can be obtained from the Great Western Exploration and Reduction Co. in Boulder, Colorado, from the Tungsten Mining Co. in Omaha, Nebraska, from the American Tungsten Mining Co. at Long Hill, Connecticut, and from the Ima Mining Co., Patterson Creek, Idaho.

**Natural Gas.**—The annual report of the United States Geological Survey, prepared by F. H. Oliphant,† gives the value of the output of natural gas in 1902 as 30,867,668 dollars, equivalent to about 205,784,453,333 cubic feet at 15 cents per 1000 cubic feet. There were 14,349 producing wells at the end of 1902, but of these 95 were shut down. During the year 2722 productive wells were completed, and there were 579 unproductive and 1238 abandoned wells.

**Accidents in Collieries.**—F. L. Hoffman‡ gives tabulated statements of accidents in collieries in the United States from 1893 to 1902.

O. Kohser§ deals with the collieries of the United States, briefly referring to the methods employed, the wages paid, and the results attained.

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\* *Centralblatt der Walzwerke*, vol. viii. p. 276.

† *United States Geological Survey; Mineral Resources*, pp. 631-655, Washington, 1904.

‡ *Engineering and Mining Journal*, vol. lxxvi. pp. 347-348, 465.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 34-38.

## XXI.—COMPARATIVE TABLES.

**The World's Production of Coal and Iron.**—For purposes of comparison the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom . . . . .	1903	230,334,469
Australasia—		
New South Wales . . . . .	1903	6,351,846
New Zealand . . . . .	1902	1,362,702
Queensland . . . . .	1903	507,801
Tasmania . . . . .	1902	48,863
Victoria . . . . .	1902	225,164
Western Australia . . . . .	1902	140,884
Austria, coal . . . . .	1902	11,045,039
" lignite . . . . .	1902	22,139,683
Hungary, coal . . . . .	1902	1,098,926
" lignite . . . . .	1902	5,103,236
Belgium . . . . .	1902	22,877,470
Borneo . . . . .	1902	50,721
Bosnia . . . . .	1903	467,962
Canada . . . . .	1903	7,996,634
Cape Colony . . . . .	1902	168,214
Chili . . . . .	1903	1,000,000
China . . . . .	1902	500,000
France . . . . .	1903	34,317,527
Germany, coal . . . . .	1903	116,637,766
" lignite . . . . .	1903	45,674,309
Greece . . . . .	1902	8,546
Holland . . . . .	1902	399,133
India . . . . .	1902	7,424,480
Italy, lignite . . . . .	1902	414,569
Japan . . . . .	1901	8,945,988
Mexico . . . . .	1902	759,634
Natal . . . . .	1902	592,821
Peru . . . . .	1901	45,000
Portugal . . . . .	1902	16,792
Roumania, lignite . . . . .	1901	105,000
Russia . . . . .	1902	15,266,871
Servia . . . . .	1902	153,764
Spain . . . . .	1903	2,700,835
Sumatra . . . . .	1902	198,581
Sweden . . . . .	1902	320,390
Transvaal . . . . .	1903	2,415,283
Turkey . . . . .	1901	200,000
United States . . . . .	1902	267,699,334

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom . . . . .	1908	8,811,204
Austria . . . . .	1902	991,826
Hungary . . . . .	1902	435,403
Belgium . . . . .	1903	1,197,275
Bosnia . . . . .	1903	39,833
Canada . . . . .	1903	265,418
France . . . . .	1903	2,827,668
Germany and Luxemburg . . . . .	1903	10,085,634
Italy . . . . .	1902	30,640
Japan . . . . .	1902	55,171
Russia . . . . .	1902	2,524,145
Spain . . . . .	1903	380,284
Sweden . . . . .	1903	506,825
United States . . . . .	1903	18,009,252

A return,\* which is compiled annually in the Home Office, contains statistics of the number of persons employed, of accidents, and of the output of minerals at mines and quarries in British colonies and foreign countries. It appears from the statistics contained in the report that the total amount of coal produced in the world in 1902 amounted to 800 million tons, the value of which is estimated at more than 270 million pounds sterling. The following figures show the main sources from which the fuel supply of the world was obtained:—

Country.	Metric Tons.	Value.
United States . . . . .	273,600,000	£75,373,000
Great Britain . . . . .	230,739,000	93,521,000
Germany . . . . .	150,600,000	52,654,000
Austria-Hungary . . . . .	39,479,000	10,528,000
France . . . . .	29,997,000	17,459,000
Belgium . . . . .	22,877,000	12,081,000

Particulars relating to the world's production of coal have also been issued by the Board of Trade.†

The Antwerp Bureau of International Statistics has published a summary of the world's pig iron production from 1850 to 1902. Figures are also given for the pig iron production of Germany,

\* *Mines and Quarries: General Report and Statistics for 1902. Part IV. Colonial and Foreign Statistics.* [Cd. 2084.] (Price 1s. 8d.)

† Cd. 312 of 1903.

Austria-Hungary, Belgium, Spain, France, Great Britain, Russia, Sweden, Japan, Canada, and the United States from 1800 to 1902.\*

The pig iron production of the various countries is shown in diagrammatic form by B. Neumann.†

Comparative coal and iron statistics are given in the report of the Dortmund Mining Society for 1903.‡

Some comparative mineral statistics for the year 1901 have been compiled by G. Johnson.§

Bennett H. Brough|| gives statistics of the world's iron ore production.

**The World's Production of Steel.**—B. Neumann¶ states that the world's steel production in 1902 was as follows:—

	Tons.
United States . . . . .	15,259,108
Germany . . . . .	7,422,449
Great Britain . . . . .	5,102,420
Russia . . . . .	1,730,250
France . . . . .	1,635,300
Austria Hungary . . . . .	1,143,900
Belgium . . . . .	776,875
Sweden . . . . .	283,500
Canada . . . . .	184,950
Spain . . . . .	124,000
Italy . . . . .	119,500
Other countries . . . . .	412,000
Total . . . . .	34,194,352

The corresponding total for 1901 was 31 million tons.

**The World's Production of Ammonium Sulphate.**—The report of the German Ammonia Sale Association for 1903 has been issued.\*\* The works belonging to the Association made 65,000 tons of ammonium sulphate in 1903. The world's production of that product in 1903 was as follows:—

\* *Moniteur des Intérêts Matériels*, vol. liv. p. 762.

† *Die Metalle*, Halle, 1904.

‡ *Jahresbericht des Vereins für die bergbaulichen Interessen*, Essen, 1904.

§ *Journal of the Canadian Mining Institute*, vol. vi. pp. 66-72.

|| *Journal of the West of Scotland Iron and Steel Institute*, vol. xi. pp. 60-71.

¶ *Chemische Zeitschrift*, vol. iii. p. 426.

\*\* *Glückauf*, vol. xl. p. 406.

	Tons.
England . . . . .	234,000
Germany . . . . .	140,000
France . . . . .	52,000
Belgium, &c. . . . .	35,000
Austria, Russia, and Spain . . . . .	45,000
United States . . . . .	70,000

**Miners' Wages.**—Details are published in tabular form which show the wages paid to the workpeople, the length of shift, the work done, and the cost of the chief articles of food at some of the chief mining centres in Austria-Hungary, Germany, and Belgium.\*

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 39.



## BIBLIOGRAPHY.

The following is a list of the principal works relating to iron and steel published during the first half of 1904 :—

## METALLURGY.

- ALLING, G. W. "*Points for the Buyers and Users of Tool Steel.*" 8vo, pp. 224, illustrated. New York: David Williams & Company. (Price 10s.)
- AURELI, A. "*La pratica della fonderia.*" 8vo, pp. 756, with 528 illustrations. Milan: U. Hoepli. (Price 20 francs.)
- BABU, L. "*Traité théorique et pratique de métallurgie générale.*" Vol. I. 8vo, pp. 588, with 148 illustrations. Paris: Béranger. (Price 25 francs.)  
[The subjects dealt with in this volume are the elements and products of metallurgical operations, classified under the following heads: ores, capital, labour, energy, electric energy, chemical energy, mechanical energy, thermal energy, combustion, production, utilisation and recuperation of heat, metals and alloys, fluxes and slags.]
- BELLOC, M. G. "*Thermo-électricité du fer et des aciers.*" 8vo, pp. 75. Paris: Gauthier-Villars. (Price 4 francs.)
- BELLUOMINI, G. "*Prontuario del peso dei metalli.*" 2nd edition. 8vo, pp. 247. Milan: Ulrico Hoepli. (Price 3s.)
- BENEDICKS, C. "*Recherches Physiques et physico-chimiques sur l'Acier au Carbon.*" 8vo, pp. 220, illustrated with 28 photomicrographs. Upsala, 1904.  
[Contains papers on the briquetting of iron ores by A. Weiskopf, on electricity in metallurgy by E. Kolben, and on the early history of iron by O. Vogel.]
- BOOTH, W. H. "*Liquid Fuel and its Combustion.*" 8vo, pp. 397, with 199 illustrations. London: Constable & Co., Ltd. (Price 24s. net).
- BORCHERS, W. "*Elektro-Metallurgie.*" 3rd edition. Part II. 8vo, with 86 illustrations. Leipzig: S. Hirzel. (Price 11s.)  
[In the first edition in 1896 the author stated that no satisfactory results had been obtained in the electric smelting of iron. In the present edition he describes the processes of Héroult, Stassano, and Kjellin.]

- "*British Engineering Standards Coded Lists*," vol. i.: "*Rolled Sections for Constructional Iron and Steel Tram Rails*." Issued by authority of the Engineering Standards Committee. 4to, pp. 475. London: R. Atkinson. (Price 21s. net.)
- BUCHANAN, J. F. "*Foundry Nomenclature: The Moulder's Pocket Dictionary*." 8vo, pp. 234. London: Spon. (Price 8s.)
- BURR, W. H. "*Elasticity and Resistance of the Materials of Engineering*." 6th edition. pp. 1016, illustrated. New York: J. Wiley & Sons. London: Chapman & Hall, Ltd. (Price \$7.50.)
- CARNOT, A. "*Traité d'analyse des substances minérales*." Vol. II. 8vo, pp. 821, illustrated. Paris: Dunod. (Price 25 francs.)
- CHASE, I. MCK. "*The Art of Pattern-Making*." pp. 254, illustrated. New York: John Wiley & Sons. (Price \$2.50.)
- COLBY, A. L. "*A Comparison of Certain Physical Properties of Nickel Steel and Carbon Steel*." 4to, pp. 103. Bethlehem, Pa: Bethlehem Steel Company.
- CONSIDÈRE, A. "*Experimental Researches on Reinforced Concrete*." Translated by L. S. Moisseiff. 8vo, pp. 188, with 20 illustrations. New York: McGraw-Hill. (Price \$2.)
- DELÉPINE, M. "*Les carbures métalliques*." 8vo, pp. 179. Paris: Joanin & Cie. (Price 3s. 6d.)
- DESCHAMPS, J. "*Les Gazogènes*." Large 8vo, pp. 432, with 240 illustrations. Paris: Dunod. (Price 15 francs.)
- DESLOGES, A. "*Les Forges de Normandie. Origine de la fabrication du fer en Normandie*." 2nd edition. 8vo, pp. 40. Verneuil: Aubert.
- FAULENBACH, F. "*Hüttenkunde*." 4to, pp. 68, with 93 illustrations. Hainichen. (Price 6s.)
- FINDLAY, A. "*The Phase Rule and its Applications*." 8vo, pp. 314, with 118 illustrations. London: Longmans, Green & Co. (Price 5s.)
- FORSTER, M. "*Die Eisenkonstruktionen der Ingenieur-Hochbauten*." 2nd edition. Leipzig: W. Engelmann. (Price 42s.)
- GUILLAUME, C. E. "*Les applications des aciers au nickel*." 8vo, pp. 215. Paris: Gauthier-Villars. (Price 3s.)
- HARBORD, F. W., and J. W. HALL. "*The Metallurgy of Steel*." 8vo, pp. 758, with 280 illustrations, 37 plates, and 100 photomicrographs. London: Charles Griffin & Co. Ltd. (Price 25s. net.)

[The book is divided into four main sections, dealing respectively with the manufacture of steel, reheating, the mechanical treatment of steel, and finished steel. The third section, which deals with rolling, hammering, forging, wire drawing, and fluid compression, from an engineering point of view, has been written by J. W. Hall. The final section is of special interest to users of steel. The testing of the various finished materials and leading types of testing-machines are described, and the influence of impurities on the mechanical properties of steel discussed. Special steels, the heat treatment of steel, and the microstructure of steel also receive careful attention. An appendix is devoted to the subject of specifications. English and American specifications are compared, and typical examples are given.]

- HÄSELER, E. "*Der Brückenbau.*" Part I. Iron Bridges. 8vo. Brunswick: Vieweg & Son. (Price 10s.)
- HEAD, A. P. "*Metallurgy as Applied in Engineering.*" 8vo, pp. 22. London: Institution of Civil Engineers.  
[Lecture delivered to the students of the Institution on January 29, 1904; deals with the location of ironworks, the metallurgy of iron, the uses of steel, high speed tool steel, definition of iron and steel, steel and iron compared, chemical composition of sound ingots, metallography, sorbitic steel, specialisation, technical education, and commerce.]
- HUBER, H. "*Gewichtstabellen für Walzeisen aus Flusseisen.*" 8vo, pp. 30. Illustrated. Friedek: Orel & Sohn. (Price 2s. 6d.)
- LAZURTEGUI, J. de. "*La reunion del Instituto del Hierro y el Acero en Barrow-in-Furness.*" 8vo, pp. 42. Bilbao.
- LEDEBUR, A. "*Das Roheisen mit besonderer Berücksichtigung seiner Verwendung für die Eisengießerei.*" 8vo, pp. 104. Leipzig: A. Felix.
- LEDEBUR, A. "*Manuel théorique et pratique de la métallurgie du fer.*" French translation by B. de Langlade and F. Valtou. 2nd edition. Vol. I. 8vo, pp. 631, with 404 illustrations. Paris: Béranger. (Price 50 francs.)
- LEU, E. "*Ausführliche Tabellen für Eisen und Holz.*" Folio, pp. 257, with 5 plates. Cologne: P. Neubner. (Price 12s.)
- LODIN, A. "*Rapports du jury international de l'Exposition de 1900. Classe 64.*" 8vo, pp. 478. Paris: Government Printer.
- LOMNITZ, H. "*Ein Weg zur Verringerung der Frachtkosten für Koks und Minette für die rheinisch-westfälische und lothringisch-luxemburgische Eisenindustrie.*" 8vo, pp. 51. Berlin: J. Springer. (Price 1s. 7d.)
- MATHIAS, E. "*Le Point Critique de Corps Purs.*" Paris: C. Wand. (Price 7 francs.)
- MÖHRING, B. "*Stein und Eisen.*" Part I. Folio, 10 plates, with 5 pages of text. Berlin. (Price 10s.)
- MURPHY, B. S. "*English and Scottish Wrought Iron-work.*" Folio, 80 plates, and descriptive text. London: B. T. Batsford. (Price £3, 3s.)  
[The plates measure 21 inches by 15 inches. All classes of decorative work are included, such as gates, railings, screens, hanging signs, and brackets; and most of the drawings are to the scale of 1 inch to the foot.]
- NEUMANN, B. "*Die Metalle: Geschichte, Vorkommen und Gewinnung.*" 8vo, pp. 418, with 26 plates. Halle: W. Knapp. (Price 16s.)  
[Sixty-four pages are devoted to iron, and diagrams are given showing the iron production from 1850 to 1902, and iron prices for the same period.]
- NEUMANN, B. "*Wandtafeln zur Metallstatistik.*" Diagram I, iron, measuring 65 by 68 centimetres. Halle: W. Knapp. (Price 3s.)
- NICHOLSON, J. T. "*Report on the Tests of High-speed Steel.*" Made at the Manchester Municipal School of Technology. 8vo, pp. 138, with 17 maps. Manchester: F. Hazelton, 29 Brown Street. (Price 2s. 6d.)

- OSMOND, F. "*Microscopic Analysis of Metals.*" Edited by J. E. Stead. 8vo, pp. 178, with 100 illustrations. London: C. Griffin & Co. Ltd. (Price 7s. 6d. net.)  
[Contains translations of papers on metallography considered as a method of testing, read at the Stockholm Congress in 1897, and on the micrographic analysis of carbon steels, an account of Osmond's most recent work published in Paris in 1901. There is also a specially written chapter on the apparatus used, and an appendix on the hardness of austenite.]
- PARSONS, H. de B. "*Steam Boilers, their Theory and Design.*" 8vo, pp. 375, with 155 illustrations. London: Longmans, Green & Co. (Price 10s. 6d. net.)  
[Deals incidentally with combustion, fuels, furnace temperature, and materials.]
- PAVLOFF, M. A. "*Album of Fifty-two Drawings relating to the Manufacture of Open-hearth Steel.*" Ekaterinoslav and London: E. & F. N. Spon. (Price 12s.)
- PONTHIÈRE, H. "*Traité d'électro-métallurgie.*" 3rd edition. Paris: Gauthier-Villars. (Price 15 francs.)
- SCHNABEL, C. "*Traité de Métallurgie Générale.*" Translated by L. Gautier. 8vo, pp. 755, with 768 illustrations. Paris: Béranger. (Price £2, 2s. 6d.)
- SIDERSKY, H. "*Essais des combustibles.*" 8vo, pp. 185. Paris: Gauthier-Villars. (Price 2s. 3d.)
- SIEMENS and HALSKE. "*Eisenprüfapparat für ganze Blechtafeln.*" 8vo, pp. 22, with 18 plates. Vienna.
- SUPLEE, H. H. "*The Mechanical Engineer's Reference-Book.*" 8vo, pp. 834. London: C. Griffin & Co. Ltd.  
[Deals incidentally with materials of construction, including methods of testing, and results of standard tests.]
- TURNER, T. "*Lectures on Iron-Founding.*" 8vo, pp. 136, with 52 illustrations and a folding plate. London: C. Griffin & Co. Ltd. (Price 3s. 6d. net.)  
[A course of five evening lectures delivered in connection with the University of Birmingham in 1903.]
- VEEN, H. J. VAN DER. "*Ijzerconstructies.*" Amsterdam: Veen. (Price 1s. 8d.)  
[The construction of iron columns, beams, and staircases.]
- VOELCKER, H. "*Das Kartellwesen in der inländischen Eisenindustrie.*" 8vo, pp. 135. Berlin: F. Siemenroth. (Price 3s. 7d.)
- VOGT, J. H. L. "*Die Silicateschmelzlösungen.*" 8vo, with 24 illustrations and 2 plates. Christiania: J. Dybwad. (Price 6s.)
- WEDDING, H. "*Ausführliches Handbuch der Eisenhüttenkunde.*" 2nd edition. 8vo. Vol. III., Part I., pp. 1-348, with 231 illustrations. Brunswick: F. Vieweg & Son. (Price 16s.)  
[This part is devoted exclusively to blast-furnace practice.]
- WEDDING, H. "*Das Eisenhüttenwesen.*" 2nd edition. 8vo, pp. 120. Leipzig: B. G. Teubner. (Price 1s.)

WOOD, M. P. "*Rustless Coatings: Corrosion and Electrolysis of Iron and Steel.*" 8vo, pp. 432, with 85 illustrations. New York: John Wiley & Sons. (Price \$4.)

ZENGHELIS, C. D. "*Στοιχεία Μεταλλουργίας.*" 8vo, pp. 314, with 61 illustrations. Athens: Nomikes. (Price 10 drachma.)

[Part II., covering 192 pages, deals with the metallurgy of iron. Reference is made to the researches of Sir Lowthian Bell, of Ledebur, and of Wedding.]

#### MINING.

AGUILLON, L. "*Législation des mines en France.*" New edition. 8vo, pp. 1015. Paris: Béranger. (Price 25 francs.)

BAYLEY, W. S. "*The Menominee Iron-Bearing District of Michigan.*" United States Geological Survey Monograph, vol. xlv. 4to, pp. 513. (Price 1.75 dollars.)

BECK, R. "*Traité des Gisements Métallifères.*" Translated by O. Chemin. 8vo, pp. 808, with 257 illustrations. Paris: C. Béranger. (Price 30 francs.)

BLOCHMANN, R. "*Schätze der Erde.*" Stuttgart. (Price 6s.)

BROUGH, B. H. "*Cantor Lectures on the Mining of Non-Metallic Minerals.*" 8vo, pp. 48, with 15 illustrations. London: Society of Arts. (Price 1s.)

BROWN, M. W. "*Subject Matter Index of Mining, Mechanical, and Metallurgical Literature for the Year 1901.*" Newcastle: North of England Institute of Mining and Mechanical Engineers. (Price 42s.)

CARNE, J. E. "*The Kerosene Shale Deposits of New South Wales.*" 4to, pp. 333, with maps, plates, and section. Sydney: Government Printer.

CLEMENTS, J. M. "*The Vermilion Iron-bearing District of Minnesota.*" 4to, pp. 464, with maps and illustrations. United States Geological Survey Monograph, vol. xlv. (Price 3½ dollars.)

"*Coalfield Directory for the Year ending April 1, 1904.*" pp. 384. Pittsburg, Pa.: Keystone Consolidated Publishing Company. (Price 6 dollars.)

COLOMER, F. "*Les mines de houille de Nouvelle-Calédonie.*" 4to, pp. 23. Fontainebleau: Bourges.

DEMARET, L. "*Les principaux gisements de minerais de fer du monde.*" 8vo, pp. 61, with 59 illustrations and 2 plates. Paris. (Price 2 francs.)

DUQUENOIS, L. "*La houille dans les Ardennes.*" 16mo, pp. 124, and 2 maps. Charleville: Didier. (Price 2 francs.)

"*Electricity in Mines: Report of the Departmental Committee.*" 8vo, pp. 30. London: Home Office.

"*Entwicklung des niederrheinisch-westfälischen Steinkohlen-Bergbaues.*" Vol. I. Geology. 4to, pp. 315, with 33 illustrations and 18 plates. Berlin: Springer.

[The work will be complete in 10 volumes, of which Vols. II. to VI. have already been published.]

- "*Ergebnisse der vom k.k. Ackerbauministerium im Jahre 1902 eingesetzten Kommission zur Untersuchung der Betriebsverhältnisse des Erzwachsbergbaues in Galicien.*" Vienna: Government Printing Office. (Price 4s.)
- ESCALES, R. "*Die Explosivstoffe.*" Part I. 8vo, pp. 114, illustrated. Leipzig: G. Fock.
- FOSTER, Sir C. Le Neve, "*The Elements of Mining and Quarrying.*" 8vo, pp. 321, with 281 illustrations. London: Charles Griffin & Co., Ltd. (Price 7s. 6d. net.)  
[The subject is treated under sixteen heads, namely: (1) occurrence, (2) discovery, (3) boring, (4) excavation, (5) support, (6) exploitation, (7) haulage, (8) hoisting, (9) drainage, (10) ventilation, (11) lighting, (12) access, (13) dressing, (14) legislation, (15) health, and (16) accidents.]
- FOSTER, Sir C. Le Neve. "*A Text-Book of Ore and Stone Mining.*" 5th edition. 8vo, pp. 763, with 716 illustrations and frontispieces. London: C. Griffin & Co., Ltd. (Price 34s.)
- GERLAND, E. "*Lehrbuch der Elektrotechnik mit besonderer Berücksichtigung ihrer Anwendung im Bergbau.*" 8vo, pp. 548, with 442 illustrations. Stuttgart: F. Enke.
- GUARDIOLA, R. "*Tratado de maquinaria con especial aplicacion a la industria minera.*" 8vo, pp. 114, with 140 illustrations. Cartagena: J. Requena. (Price 3s.)
- GUARINI, E. "*L'Electricité dans les Mines en Europe.*" Translated from the *Engineering Magazine*. 8vo, pp. 46, with 30 illustrations. Brussels: Ramlot Frères et Soeurs. (Price 5 francs.)
- HAANEL, E. "*The Location and Examination of Magnetic Ore Deposits by Magnetometric Measurements.*" 8vo, pp. 132, with 8 folding plates. Ottawa, Canada: Department of the Interior.
- HABETS, A. "*Cours d'Exploitation des Mines.*" Vol. II. 8vo, pp. 643. Liège.
- HAUSDING, A. "*Handbuch de Torfgewinnung und Torfverwerthung.*" 2nd edition. 8vo, with 151 illustrations. Berlin: P. Parey. (Price 15s.)
- HEISE, F. "*Sprengstoffe und Zündung der Sprengschüsse.*" 8vo, pp. 241, with 146 illustrations. Berlin: J. Springer. (Price 7s.)
- HOFER, H. "*Taschenbuch für Bergmänner.*" 2nd edition. 8vo, pp. 829, with 317 illustrations. Leoben: L. Nüssler. (Price 14s.)
- HÖRHAGER, J. "*Bergbaue Steiermarks.*" Vol. III. Leoben: L. Nüssler. (Price 1s. 8d.)  
[Dealing with the occurrence of iron ore at Neumarkt in Upper Styria.]
- HUGHES, H. W. "*A Text-Book of Coal Mining.*" 5th edition. 8vo, pp. 563, with 690 illustrations and 4 plates. London: C. Griffin & Co., Ltd. (Price 24s. net.)
- IBOTSON, J. G. P. "*Quarry and Stone Merchants' Accounts.*" 8vo. London: Gee & Co. (Price 3s. 6d. net.)
- "*Outlines of the Geology of Japan.*" Part III. Economic Geology. Tokyo: Geological Survey of Japan.

- KALECZINSKY, A. VON. "*Die Mineralkohlen der Länder der ungarischen Krone.*" With map. Budapest: Franklin Verein. (Price 14s.)
- KÖHLER, H. "*Chemie und Technologie der natürlichen und künstlichen Asphalte.*" 8vo, with 191 illustrations. Brunswick. (Price 15s.)
- KIESLINGER, F., and others. "*Die Mineralkohlen Österreichs.*" 8vo, pp. 492, with atlas of 12 plates. Vienna: Published by the Committee of the Mining Congress. (Price 25s.)
- KISSLING, E. "*Die schweizerischen Molassekohlen westlich der Reuss.*" 8vo, pp. 76, with 3 plates. Bern: A. Francke. (Price 4 francs.)
- "*Die Königlich Sächsische Bergakademie zu Freiberg.*" 4to, pp. 97, illustrated. Freiberg: Craz & Gerlach. (Price 4s.)
- [A volume prepared for the educational collection at the St. Louis Exhibition.]
- KUSS, H., and L. FÉVRE. "*Traité de l'exploitation des mines.*" Parts 1 to 36. 8vo, pp. 378. Paris: Fanchon. (Price 6d. each.)
- LANDES, H. and C. A. RUDDY. "*Coal Deposits of Washington.*" Washington Geological Survey, Annual Report, 1902. Vol. II. pp. 165-277.
- LAUNAY, L. DE. "*L'origine et les caractères des gisements de fer scandinaves.*" 8vo, 6 plates. Paris: Dunod. (Price 4½ francs.)
- LEAVITT, T. H. "*Facts about Peat.*" 8vo, pp. 115. Boston, U.S.A.: Lee & Shepard. (Price 4s.)
- LENICQUE, H. "*Etat actuel de la préparation mécanique des minerais.*" 8vo, pp. 71, with 13 illustrations and 1 plate. Paris: Dunod. (Price 3 francs.)
- LINDLEY, C. H. "*A Treatise on the American Law Relating to Mines and Mineral Lands.*" Vol. I, pp. 936; Vol. II, pp. 1216. San Francisco: The Bancroft-Whitney Company. (Price 75s.)
- MERRILL, G. P. "*The Non-Metallic Minerals: their Occurrence and Uses.*" 8vo, pp. 414, with 32 plates and 28 illustrations. New York: John Wiley & Sons. (Price 17s. net.)
- [Contains information and references relative to chrome iron ore, manganese ore, bauxite, limestone, dolomite, magnesite, coals, bitumens, and moulding-sand.]
- MILLER, E. H. "*Quantitative Analysis for Mining Engineers.*" 8vo, pp. 144. New York: The D. Van Nostrand Company. (Price \$1.50.)
- MITCHELL, T. "*Monmouthshire Iron and Steel Trade.*" 8vo, pp. 26. Newport: J. E. Southall. (Price 6d.)
- MOSTACCIO, L. "*Il carbon fossile italiano in Agnana Calabria.*" 8vo, pp. 38. Conegliano: Nardi.
- "*Mount Kembla Colliery Disaster.*" Report of the Royal Commission, N.S.W. Legislative Assembly. Sydney: W. A. Gulich. (Price 10s.)
- MÜLLER-LANDSMANN, J. R. "*Das Eisenbergwerk im Oberhasle, Kanton Bern, Schweiz.*" 8vo, pp. 103, with 3 illustrations. Zürich: J. Frey.
- REBOUD, A. "*L'Electricité et ses Applications.*" Part II. 8vo, pp. 377. Paris: Ch. Béranger. (Price 8s. 6d.)

- RICKARD, T. A. "*Sampling and Estimation of Ore in a Mine.*" Illustrated. pp. 220. New York: Engineering and Mining Journal. (Price 8s. 6d. net.)
- RIES, H. "*Uses of Peat and its Occurrence in New York.*" pp. 90, illustrated. Albany, N.Y.; University of the State of New York. (Price 10 cents.)
- ROBERTS, P. "*Anthracite Coal Communities.*" 8vo, pp. 387, with 28 plates. New York: The Macmillan Co. (Price 15s. net.)
- ROLIN, H. "*Les Institutions ouvrières des Charbonnages de Mariemont et de Bascoup.*" Brussels. (Price 7 francs.)
- RUMIN, W. "*Elementary Technical Mineralogy.*" 8vo, pp. 74. Kharkoff. (Price 2s. 6d.)  
[A description of the more important minerals of economic value in Russian.]
- SCHNELLE, F. O. "*Die neuesten Fortschritte auf dem Gebiete der magnetischen Aufbereitung.*" 4to. Illustrated. Freiberg: Craz & Gerlach. (Price 1s.)
- SOHIER, A., and G. MASSART. "*Étude sur l'emploi de l'air comprimé à haute tension comme moyen de transport mécanique souterrain.*" 8vo, pp. 100, illustrated. Paris: Dunod. (Price 3 francs.)
- SONNENSCHN, A. "*Der deutscher Unterricht an bergmännischen Fortbildungsschulen.*" 2nd edition. Hattingen.
- SSAPELKIN, W., and M. IVANOFF. "*Mining in Russia: Directory of Mines in European and Asiatic Russia, with Statistics for 1901 and two maps.*" 8vo, pp. 1594. St. Petersburg [in Russian]. (Price 45s.)
- STEIN, P. "*Der gegenwärtige Stand der Tiefbohrtechnik für Schurfzwecke.*" 8vo, pp. 48. Vienna: Manz. (Price 2s.)
- STONE, E. H. "*Mechanical Shipment of Coal: A Brief Account of the Principal Systems in Great Britain and other Countries, with a Note on the System recommended for the Calcutta Docks.*" Calcutta: Government of Bengal. (Price 12s.)
- "*Studio geologico-minerario sui giacimenti di antracite nelle Alpi occidentali italiane.*" 8vo, pp. 232, with 31 illustrations and 14 plates. Rome: Government Printer.  
[Contains six memoirs by different authors on Italian anthracite deposits.]
- THOMPSON, A. B. "*The Oil-Fields of Russia and the Russian Petroleum Industry.*" Pp. 152, with six plates and 155 illustrations. London: Crosby Lockwood & Son. (Price 63s. net.)
- TWELVETREES, W. H. "*Report on Sandfly Coal Mines.*" pp. 12. Hobart.
- VILLAIN, F. "*Le gisement des minerais de fer en Meurthe-et-Moselle.*" 8vo, pp. 22, with 5 plates. Paris. (Price 5 francs.)
- VOLK, C. "*Haulage and Winding Appliances.*" Translated by C. Salter. London, pp. 504: Scott, Greenwood & Co. (Price 8s. 6d. net.)





# INDEX.

## A.

- ABRAHAM, A., on gas power plant, 537.  
Account of income and expenditure, 18.  
Acid-proof castings, 595.  
Ackermann, A. S. E., on underground haulage, 544.  
Adams, Edwin, elected member, 1.  
Adams, G. L., on coal in Kansas, 512.  
Additions in the open-hearth process, 621.  
Additions to the library, 453.  
Aguillon, L., book on mining by, 728.  
Ainsworth, G., on the Hüssener coke oven, 202.  
Åkerman, R., on iron trade statistics of Sweden, 714.  
Alaska, coal in, 512.  
Alayza y Paz-Soldan, F., on coal in Peru, 513.  
Albania, petroleum in, 526.  
Aliamet, M., on determination of critical points, 652.  
Alio, J., on petroleum in Spain, 526.  
Allen, Cecil, elected member, 1.  
Alling, G. W., book on metallurgy by, 724.  
Allott, Matthew Henry, elected member, 1.  
Alloys, special iron, 655.  
Alsace-Lorraine, mineral statistics of, 703.  
Alternate stresses, effect of, 662.  
Althaus, on compressed air in mines, 547.  
Althouse, H. W., on coal in Virginia, 513.  
Alverstone, Lord, speech by, 442.  
Amazon, iron ore on the, 481.  
America, oldest ironworks in, 579.  
American Bessemer plant, 635.  
American blast-furnace practice, 573.  
American open-hearth steel plants, 629.  
American rolling mill plant, 610.  
Ammon, L. von, on coal in Germany, 507.  
Ammonium sulphate, world's production of, 722.  
Analysis, coal, 690.  
Analysis, gas, 690.  
Analysis, ironworks, 680.  
Analysis of basic slag, 689.  
Analysis of fuel, 689.  
Analysis of gases in pig iron, 583.  
Analysis of iron and steel, 680.  
Analysis of iron ores and slag, 687.  
Analysis of minette, 687.  
Ancient slags from Elba, composition of, 588.  
1904.—i.

- Anderson, James, elected member, 1.  
 Anderson, W. R., on coal in Victoria, 510.  
 Angerman, C., on petroleum in Austria, 525.  
 Ankylostomiasis, 556.  
 Annual dinner, 437.  
 Annual general meeting, 1.  
 Argentina, coal in, 513.  
 Argyll, Duke of, speech by, 438.  
 Armour tests, 674.  
 Arnold, Sir Alfred, elected member, 2.  
 Arnold, J. O., on critical ranges of iron carbon alloys, 247.  
 Arnold, J. O., on pyrometers, 177.  
 Arnold, J. O., on the synthesis of Bessemer steel, 306.  
 Arsenic in coal, 515.  
 Artificial gas, 534.  
 Ashland mine, shaft at, 487.  
 Ashley, G. H., on coal in the United States, 511.  
 Ashworth, J., on coal-dust explosions, 554.  
 Asia Minor, coal in, 511.  
 Asphalt, 530.  
 Ast, W., on rails, 673.  
 Atomic weight of iron, 675.  
 Auchy, G., on determination of carbon, 681.  
 Aureli, A., book on metallurgy by, 724.  
 Austria, coal in, 505.  
 Austria, iron ore in, 464.  
 Austria, manganese ore in, 481.  
 Austria, natural gas in, 534.  
 Austria, petroleum in, 524.  
 Austria-Hungary, mineral statistics of, 694.  
 Austrian cokes, 523.

## B.

- BABU, L., book on metallurgy by, 724.  
 Bacci, Carlo, elected member, 2.  
 Bach, C., on strength of steel castings as affected by temperature, 671.  
 Baelé, L., on continental rolling mill plant, 609.  
 Bagdad railway, petroleum near, 526.  
 Bagley, Chas. Henry F., elected member, 2.  
 Bagnall-Wild, Lieut. Ralph Kirby, R.E., elected member, 2.  
 Baird and Tatlock pyrometer, 99.  
 Baker, D., on gas and tar as fuel, 622.  
 Baker, D., on stock distribution in the blast-furnace, 562.  
 Baker, J. H., on steel forgings, 607.  
 Balance-sheet, 1903, 19.  
 Balbiano, L., on petroleum in Italy, 526.  
 Ball magnetic concentrator, 494.  
 Balling, K., on mining thick brown coal, 551.  
 Banaston, von, on shaft sinking, 540.  
 Barba, W. P., on steel castings, 641.  
 Barkow, on gas producers, 536.  
 Barrows, W. A., on Mesabi ores at blast-furnaces, 577.  
 Bartlett, C. O., on firing with coal dust, 559.  
 Basic Bessemer slag, 636.  
 Basic open-hearth steel, 623.  
 Basic slag, analysis of, 689.

- Bates, Herbert, elected member, 2.  
 Bauer, M., on mineral characteristics of iron ore, 463.  
 Bauerman, H., vote of thanks by, 20.  
 Baum, on coke-oven gases, 519.  
 Baum, on dangers from electricity in mines, 546.  
 Bauxite, 498.  
 Baxter, G. P., on atomic weight of iron, 675.  
 Bayley, W. S., book on mining by, 728.  
 Bayley, W. S., on Lake Superior iron ores, 475.  
 Beardshaw, W. F., on thermal treatment of steel, 75.  
 Beck, R., book on mining by, 728.  
 Beck, R., on nickel ore, 483.  
 Bedford, William James, elected member, 2.  
 Beehive coke, 516.  
 Beilby, G. T., on surface structure of solids, 647.  
 Belgium, coal in, 505.  
 Belgium, mineral statistics of, 696.  
 Belgium, steelworks of, 697.  
 Bell, C. Lowthian, *paper* on "The manufacture of coke in the Hüssener oven at the Clarence ironworks, and its value in the blast-furnaces," 188; analysis of coal, 188; form of oven, 189; analysis of gas, 190; analysis of coke, 190; results of experiments, 192; carbonic oxide contained in the coke, 193; differences between the Hüssener and other ovens, 194; analyses of gases from ovens, 196; hardness of the coke, 197; production of coke, 198; its behaviour in the furnaces, 199; make of iron per week, 200.—*Discussion*: G. Ainsworth, 202; W. Hawdon, 202; J. Riley, 205; F. A. E. Samuelson, 205; W. Hiby, 206; E. James, 209; T. Westgarth, 210; S. Rideal, 212; P. Dvorkovitz, 212; W. Hiby, 214; B. H. Thwaite, 214; W. P. Kirkpatrick, 214; C. Lowthian Bell, 216.—*Correspondence*: J. H. Darby, 219; J. Ingleby, 222; J. Parry, 223.  
 Bell, Sir Lowthian, motion on statement of accounts, 20.  
 Bell, Sir Lowthian, on pyrometers, 174.  
 Bell, Sir Lowthian, on the synthesis of Bessemer steel, 306.  
 Bell, Sir Lowthian, vote of thanks to Institution of Civil Engineers, 260.  
 Belloc, G., book on metallurgy by, 724.  
 Belloc, G., on magnetic properties of iron, 651.  
 Belluomini, G., book on metallurgy by, 724.  
 Benedicks, C., book on metallurgy by, 724.  
 Benedicks, C., on crystallisation of iron, 647.  
 Bénier's gas producer, 536.  
 Bennie, P. M'N., on electric smelting of iron ore, 605.  
 Berg, G., on iron ores in Germany, 466.  
 Berg, P. Torsten, elected member, 2.  
 Bernhardi, on the water-flush system in mines, 549.  
 Berwerth, F., on recent researches on meteorites, 484.  
 Bessemer and open-hearth process, mixed, 637.  
 Bessemer Gold Medal (1904), presentation of, 22.  
 Bessemer plant, American, 635.  
 Bessemer process, 630.  
 Bessemer slag, basic, 636.  
 Bessemer steel, synthesis of, 291.  
 Best, A., on petroleum in Louisiana, 530.  
 Best, Frederick, elected member, 2.  
 Beutner, V., on tube rolling, 615.  
 Beyer, T. W., on coal in Iowa, 512.  
 Bibliography, 724.  
 Bibliography relating to pyrometry, 154.  
 Bickford, J. S. V., on oil-fuel burners, 533.

- Bigge, D. Selby, on electric winding, 542.  
 Birkinbine, J., on production of iron ores in United States, 717.  
 Birkinbine, J., on production of manganese ore in United States, 718.  
 Blakemore, W., on coal and coke supply of British Columbia, 698.  
 Blakey, D. T., on the Stewart coal washer, 558.  
 Blanc, F., on coal washing, 558.  
 Blanckenhorn, M., on asphalt, 532.  
 Blast-furnace burdens, calculation of, 583.  
 Blast-furnace construction, 562.  
 Blast-furnace engines, 568.  
 Blast-furnace, flue dirt and top pressure in, 563.  
 Blast-furnace fuel, 566.  
 Blast-furnace gas, motive power from, 568.  
 Blast-furnace hearth area, 563.  
 Blast-furnace lining, failure of, 564.  
 Blast-furnace practice, 562, 571.  
 Blast-furnace slags, 585.  
 Blast-furnace, thermal efficiency of, 211.  
 Blasting in mines, 547.  
 Bleckly, W. H., on statement of accounts, 17.  
 Blochmann, R., book on mining by, 728.  
 Blossfeld safety brake, 543.  
 Blowholes, preventing, in ingots and castings, 641.  
 Blowing engines for blast-furnaces, 568.  
 Blyde, J. E. Alger, elected member, 2.  
 Bohemia, brown coal in, 695.  
 Boiler plates, faulty, 660.  
 Bokhara, coal in, 511.  
 Bollinokx gas producer, 536.  
 Bolstad, I., on iron industry of Brazil, 713.  
 Booth, Philip Lancashire, elected member, 2.  
 Booth, W. H., book on metallurgy by, 724.  
 Borchers, W., book on metallurgy by, 724.  
 Boright, S. H., on iron ore in Canada, 473.  
 Boring for petroleum, 533.  
 Bose, P. N., on coal in India, 510.  
 Bose, P. N., on fireclay, 496.  
 Bosnia and Herzegovina, mineral statistics of, 696.  
 Bosnia, iron ore in, 465.  
 Böttcher, O., on analysis of basic slag, 689.  
 Bouasse, H., on elastic limit, 649.  
 Bouché, C., on winding engines, 542.  
 Boucher, E., on wire ropeway at Elba ironworks, 571.  
 Boudouard, O., on determination of critical points, 653.  
 Boudouard, O., on nickel steel, 659.  
 Boudouard, O., special Carnegie medal awarded to, 1903, 15.  
 Bourgeois, R., on mine surveying, 555.  
 Bousse conveyor, 489.  
 Bouvier, on shaft sinking, 539.  
 Bowman gas producer, 536.  
 Bowman, Harold Edelsten, elected member, 2.  
 Boynton, H. C., on metallography, 650.  
 Boynton, H. C., *paper* on "Troostite," early history, 262; recognition of troostite, 264; definition of troostite, 266; evidence as to existence of troostite, 268; constitution of troostite, 279; sorbite and troostite, 285; conclusions, 287.  
     —*Correspondence*: F. Osmond, 288; H. Le Chateller, 290.  
 Boys, C. V., on use of thermite for castings, 642.

- Braae, J. H., on shaft sinking, 540.  
 Brame, J. S. S., on calorimetry, 501.  
 Bräuer, K., on gas producers, 536.  
 Braun, R., on mineralogical characteristics of iron ore, 463.  
 Bräunlich, F., on composition of coal, 504.  
 Brauns, H., on the Duff system of gas production, 534.  
 Brauss, on coal analysis, 690.  
 Brazil, coal in, 513.  
 Brazil, iron industry of, 713.  
 Bremme, F., obituary notice of, 446.  
 Breton, on coal in France, 506.  
 Breuil, P., *abstract of paper* on "Relations between stresses slowly applied and stresses suddenly applied in the case of steel," 413; slow tensile tests, 414; slow bending tests, 416; impact bending tests, 418. See supplementary volume.  
 Breuil, P., presentation of Carnegie Gold Medal to, 25, 27.  
 Brewer, W. M., on coal in Canada, 510.  
 Brezezowski, on permitted explosions in Austrian mines, 547.  
 Brightmore, Frederick, elected member, 2.  
 Briquettes, 560.  
 Briquettes, manufacture of pig iron from, at Herräng, 40.  
 Briquetting ore, 495.  
 Bristol's recording air pyrometer, 101.  
 Brittleness of steel, 655.  
 Broadhead, G. C., on petroleum in Missouri, 529.  
 Broma, G. E., obituary notice of, 446.  
 Brough, B. H., book on mining by, 728.  
 Brough, B. H., member of pyrometer committee, 89.  
 Brough, B. H., on iron ores in Luxemburg, 467.  
 Brough, B. H., on magnesite, 498.  
 Brough, B. H., on magnetic ore deposits, 486.  
 Brough, B. H., on medals associated with the iron industry, 579.  
 Brough, B. H., on mine surveying, 555.  
 Brough, B. H., on use of blast-furnace gas, 569.  
 Brough, B. H., on world's iron ore production, 722.  
 Brown coal, coking of, 521.  
 Brown coal producer gas, 538.  
 Brown, Myles, on calorific value of coal, 502.  
 Brown, M. W., book on mining by, 728.  
 Brunck, O., on fractional combustion, 690.  
 Brunck, O., on ironworks analysis, 680.  
 Buchanan, J. F., book on metallurgy by, 725.  
 Buhle, M., on handling ore, 489.  
 Buhle, M., on underground haulage, 544.  
 Bunch, Charles Edward, elected member, 2.  
 Burmann, S., on determination of titanium, 686.  
 Burns, D., on coal cutting, 549.  
 Burnyeat, Richard Whiteside, elected member, 2.  
 Burr, W. H., book on metallurgy by, 725.  
 Burtt, William Henry, elected member, 2.  
 Butchart, A., presentation to, 12.  
 By-product coke, 517.  
 Byström, A., on charcoal blast-furnaces, 564.  
 Byström, A., on Russian steelworks, 628.

## C.

- CADMAN, J. C., on calcining ores, 495.  
 Cadman, J. C., on iron ore in North Staffordshire, 464.

- Calcoining iron ore, 495.  
 Calculation of blast-furnace burners, 583.  
 Caldwell, B. P., on use of thermite for castings, 642.  
 California, petroleum in, 528.  
 Callendar & Griffith's thermometers, 103.  
 Callendar, H. L., on pyrometry, 502.  
 Calorific value of fuel, 501.  
 Calorimetry, 501.  
 Campbell, M. R., on coal in the United States, 511.  
 Campion, A., Carnegie Gold Medal, 1903, presented to, 15.  
 Campion, A., on pyrometers, 165.  
 Campion, A., on variations in structure and tests of steel, 668.  
 Canada, coal in, 510.  
 Canada, iron ore in, 473.  
 Canada, mineral statistics of, 697.  
 Canada, petroleum in, 527.  
 Canadian blast-furnaces, 571.  
 Capp, J. A., on magnetic properties of iron, 651.  
 Carbon, determination of, 681.  
 Carborundum in the cupola, 594.  
 Carburisation of malleable iron, 617.  
 Carbutt, Sir E. H., on critical ranges of iron carbon alloys, 245.  
 Card, G. W., on meteorites, 484.  
 Carl Lueg Gold Medal, institution of, 579.  
 Carlsson, Hugo, elected member, 2.  
 Carne, J. E., book on mining by, 728.  
 Carne, J. E., on oil shale, 530.  
 Carnegie, A., speech on presentation of Bessemer Medal, 23.  
 Carnegie, A., speech on presentation of Carnegie Gold Medal, 26.  
 Carnegie, A., speech on presentation of Carnegie Special Silver Medal, 28.  
 Carnegie, A., speeches at annual dinner, 437, 443.  
 Carnegie, A., speeches at meeting, 21, 22.  
 Carnegie Gold Medal, presentation of, 25, 27.  
 Carnegie Special Silver Medal, presentation of, 25, 27.  
 Carnot, A., book on metallurgy by, 725.  
 Carpenter, Henry Cort Harold, elected member, 2.  
 Carpenter, H. C. H., and B. F. E. Keeling, *paper* on "The range of solidification and the critical ranges of iron carbon alloys," 224; measurement of temperatures, 224; method of determining the range of solidification, 227; tabulated chemical analysis of alloys, 229; beginning of the solidification, 231; end of the solidification, 231; table of range of solidification and of critical ranges, 232-233; the critical changes of the alloys, 235; separation of massive cementite, 239; heating curves, 241; conclusions, 241.—*Discussion*: J. A. Ewing, 243; Sir E. H. Carbutt, 245; H. Le Chatelier, 247; J. O. Arnold, 247; R. A. Hadfield, 249; R. T. Glazebrook, 249; R. A. Hadfield, 250; A. McWilliam, 250; B. F. E. Keeling, 252; H. C. H. Carpenter, 252.—*Correspondence*: F. Osmond, 253; J. Parry, 255; T. K. Rose, 256; Bakhuis Roozeboom, 257; H. C. H. Carpenter, 259; B. F. E. Keeling, 259.  
 Carper, J. B., on rock drills, 486.  
 Carr, William M., elected member, 2.  
 Cartaud, G., on metallography, 649, 650.  
 Carulla, F. J. R., *paper* on "The synthesis of Bessemer steel," 291; introduction, 291; the process, 292; the speiseleisen and the ferro-manganese, 294; the carbon, 295; the manganese, 296; rail steel, 299; steel for axles, 300; steel for tires, 301; spring steel, 301; conical springs, 301; conclusions, 305.—*Correspondence*: J. O. Arnold, 306; Sir L. Bell, 306; A. H. Cooper, 306; P. C. Gilchrist, 307; R. A. Hadfield, 307; C. Johns, 308; F. J. R. Carulla, 308.

- Carulla, F. J. R., on thermal treatment of steel, 184.  
Cast iron, defects in, 589.  
Cast iron, oxygen and sulphur in, 675.  
Cast iron, physics of, 663.  
Cast iron pipes, 673.  
Cast iron, specifications for, 672.  
Cast iron, strength and structure of, 666.  
Cast iron, testing, 664.  
Castings, acid-proof, 595.  
Castings, cleaning, with weak acid, 595.  
Castings, large, 596.  
Castings, malleable, 599.  
Castings, preventing blowholes in, 641.  
Castings, small open-hearths for, 626.  
Castings, steel, 641.  
Castings, use of thermite for, 641.  
Catlett, C., on manganese ore in the United States, 482.  
Cecil, Lord Hugh, speech by, 438.  
Cement from blast-furnace slag, 587.  
Chain haulage in collieries, 544.  
Charcoal, 515.  
Charcoal blast-furnaces, 564.  
Charcoal kilns, 515.  
Charentenay, L. de, on electric plant in mines, 546.  
Charging machines, 626.  
Charitschkoff, K. W., on petroleum in Russia, 526.  
Charlton, W., on hand drills in mining, 486.  
Charpy, G., on tests of metals, 668.  
Chase, I. McK., book on metallurgy by, 725.  
Chatwood, Arthur Brunel, B.Sc., elected member, 2.  
Chelius, C., on iron ore in Germany, 465.  
Chemical analysis, 680.  
Chemical composition of pig iron, 580.  
Chemical properties, 675.  
Chemistry of petroleum, 524.  
Chili, manganese ore in, 482.  
Chilled wheels, 645.  
China, coal in, 514.  
Chrome ore in India, 482.  
Church, J. A., ventilation of collieries, 553.  
Circular steel plates, strength of, 672.  
Claessen, on explosives, 548.  
Clamens, Jean Baptiste, elected member, 2.  
Clarence ironworks, Middlesbrough, manufacture of coke at, 188.  
Clark, Eugene B., elected member, 2.  
Classes of pig iron, 580.  
Cleaning castings with weak acid, 595.  
Cleaning cupola gases, 589.  
Clements, J. M., book on mining by, 728.  
Clements, J. M., on iron ore mining in Minnesota, 488.  
Clements, J. M., on Lake Superior iron ores, 476.  
Clements, Olaf P., elected member, 2.  
Clough, Thomas Carter, elected member, 3.  
Coal, 504.  
Coal analysis, 690.  
Coal and iron, world's production of, 720.  
Coal ash, 690.



- Coal, calorific value of, 501.
- Coal, composition of, 504.
- Coal-compressing machines, 520.
- Coal-dust explosions, 554.
- Coal-dust, firing with, 559.
- Coal-handling appliances, 558.
- Coal-mining, 538.
- Coal-mining, history of, 555.
- Coal, origin of, 505.
- Coal storage under water, 515.
- Coal transport in Germany, 703.
- Coal washing and screening, 557.
- Coates, C. E., on petroleum in Louisiana, 530.
- Cobalt ores, 483.
- Cobalt steel, 655.
- Cobb, J. W., on coal ash, 690.
- Coignard, on coal in France, 507.
- Coke, 516.
- Coke, by-product, 517.
- Coke manufacture in the Hüssener oven, 188.
- Coke, quenching, 517.
- Coke-oven gases, utilisation of, 519.
- Coke-oven plant, modern, 520.
- Coking brown coal, 521.
- Colby, A. L., book on metallurgy by, 725.
- Colby, A. L., on nickel steel, 659.
- Cold working of steel, 640.
- Collier, A. J., on coal in Alaska, 512.
- Collieries, drainage of, 551.
- Collieries, lighting of, 554.
- Collieries, sanitation in, 556.
- Collieries, ventilation of, 553.
- Colomer, F., book on mining by, 728.
- Colorado, coal in, 512.
- Colorado, petroleum in, 528.
- Colvocoresses, G. M., on cobalt ore in New Caledonia, 483.
- Comber, A. W., on ancient slags from Elba, 588.
- Combustion, fractional, 690.
- Comparative tables, 720.
- Comparison of small and large mill plant, 609.
- Composition of coal, 504.
- Composition of iron ores, 462.
- Compressed air in mines, 547.
- Considère, A., book on metallurgy by, 725.
- Construction of cranes in Germany, 645.
- Continental rolling mill plant, 609.
- Continuous practice in a fixed hearth, 624.
- Contreras, A., on mineral statistics of Spain, 713.
- Converter accessories, 635.
- Converters, small, 630.
- Cook, E. S., on specifications for cast iron, 672.
- Cooper, A. H., on the synthesis of Bessemer steel, 306.
- Coppée, Evence, jun., elected member, 3.
- Cordier, H., on ancient iron mines, 578.
- Cormack, A. C., on electricity in mines, 546.
- Corrosion of iron and steel, 676.
- Cottier, S., on coal in the United States, 511.

Council, report of, 9.  
 Cowan, John, elected member, 3.  
 Cowan, W. A., on calorimetry, 501.  
 Coward, E., obituary notice of, 446.  
 Craig, W. D., on ironworks analysis, 680.  
 Crane, W. R., on asphalt, 532.  
 Crane, W. R., on pillar and stall working in India, 551.  
 Cranes in Germany, construction of, 645.  
 Critical points, determination of, 652.  
 Crosby, W. O., on iron ore in New York, 477.  
 Crossley gas producers, 535, 536.  
 Croy, K., on methods of mining brown coal, 551.  
 Crucible furnace in foundry practice, 592.  
 Crucible steel furnace, thermal balance of a, 618.  
 Crucible steel, manufacture of, 617.  
 Crystallisation of iron, 647.  
 Cuba, iron ore in, 481.  
 Cuba, manganese ore in, 482.  
 Cupola, carborundum in, 594.  
 Cupola, fluorspar in, 595.  
 Cupola gases, cleaning, 589.  
 Cupola, limestone in, 594.  
 Cupola, loss of iron in, 589.  
 Cupola, manganese ore in, 594.  
 Cupolas, fore-hearths to, 590.  
 Cuvelette, on deep boring, 538.

## D.

DAELEN, R. M., on continuous practice in a fixed hearth, 625.  
 Daelen, R. M., on thermal treatment of steel, 87.  
 Daft, L. J., on coal cutting, 548.  
 Danielson, E., on electric power in the rolling mills, 613.  
 Darby, J. H., on coke in the Hüssener oven, 219.  
 Daube, O., on Classen residues, 516.  
 Davenport, John Edward, elected member, 3.  
 Davenport, R. W., obituary notice of, 446.  
 Davey, H., on mine drainage, 551.  
 Davie, William Synnington, elected member, 3.  
 Davis, G. C., on ironworks analysis, 680.  
 Deep boring, 538.  
 Defays, Victor, elected member, 3.  
 Defects in cast iron, 589.  
 D'Inwilliers, E. V., on beehive coke, 516.  
 Delépine, M., book on metallurgy by, 725.  
 Dellwik-Fleischer system, 536.  
 Demaret, L., book on mining by, 728.  
 Demaret, L., on origin of petroleum, 524.  
 Demeure, A., on methods of working in mines, 551.  
 Denoël, L., on coal analysis, 690.  
 Deschamps, J., book on metallurgy by, 725.  
 Deschamps, J., on gas consumers, 535.  
 Design of rolls, 607.  
 Desloges, A., book on metallurgy by, 725.  
 Determination of critical points, 652.  
 Detienne, H., on Portland cement from blast-furnace slag, 587.  
 Deutz gas producer, 536.

- Dickson, James, elected member, 3.  
 Diegel, on corrosion of iron and steel, 677.  
 Digby, W. P., on iron and steel industries, 694.  
 Dill, W., on coal in Germany, 507.  
 Dill, W., on safety catches for winding, 543.  
 Diller, J. S., on iron ore in the United States, 474.  
 Dillner, G., on elastic limit, 648.  
 Dinner, the annual, 437.  
 Distinctions conferred upon members, 9.  
 Divis, J., on condensation plant, 541.  
 Divis, J., on Riedler compressors in mines, 547.  
 Dixon, J., on coal in New South Wales, 510.  
 Dixon, W., appointed scrutineer, 1.  
 Docharty, W. C., on rock drills, 486.  
 Döll, E., on mineralogical characteristics of iron ore, 464.  
 Dombrowski, L., on manufacture of tin-plates, 646.  
 Donaldson, William Anderson, elected member, 3.  
 Donath, E., on composition of coal, 504.  
 Dondelinger, A., on converter accessories, 635.  
 Doors for heating pits, 641.  
 Dorstewitz, on open cast workings in brown coal, 551.  
 Dougherty, G. T., on determination of sulphur, 683.  
 Downe, Henry Smith, elected member, 3.  
 Drainage of mines, 551.  
 Drake, F., on winding plant at Oliver mine, 487.  
 Driver, Augustus Henry Murray, elected member, 3.  
 Drying ores at blast-furnaces, 578.  
 Dudley, C. B., on effect of alternate stresses, 662.  
 Duff gas producer, 534.  
 Dujardin, P. F., on additions in the open-hearth process, 621.  
 Dumas, Louis Charles, elected member, 3.  
 Dumas, L., on nickel steel, 659.  
 Duparc, L., on iron ore in Russia, 467.  
 Dupré, A., and M. B. Lloyd, *paper* on "Explosions produced by ferro-silicon," 30;  
     circumstances of the explosion, 30; cause of the explosion, 31; precaution to  
     avoid risk in future, 33; further experiments, 34.—*Discussion*: G. W. Gray,  
     35; J. E. Stead, 37; F. W. Harbord, 37; H. Le Chatelier, 38; M. B. Lloyd,  
     38.—*Correspondence*: J. Parry, 39.  
 Duquenois, L., book on mining by, 728.  
 Dust, emission of, from blast-furnaces, 577.  
 Dvorkovitz, P., on coke in the Hüssener oven, 212.

## E.

- EARLY history of iron, 578.  
 Earp, Henry Proctor, elected member, 3.  
 Earth tremors as regards collieries, 553.  
 Eckardt, H., on small open-hearths for castings, 626.  
 Eckel, E. C., on iron ore in the United States, 474.  
 Eckel, E. C., on utilisation of blast-furnace slags, 585.  
 Eckelt, J. L. C., on cleaning castings with weak acid, 595.  
 Edwards, H. W., on slag concrete, 587.  
 Edwards, V. E., on rolling mill engines, 614.  
 Effect of alternate stresses, 662.  
 Effect of repeated heating on iron and steel, 654.  
 Egger, on electric mine locomotives, 545.  
 Elastic limit, 648.

- Elba, blast-furnace plant at, 571.  
 Eldridge, G. H., on petroleum in the United States, 527.  
 Electric power in the rolling mills, 613.  
 Electric production of iron alloys, 606.  
 Electric smelting of iron ore, 603.  
 Electric welding, 642.  
 Electric winding engines, 542.  
 Electricity in mines, *report of Home Office Committee on*, 545.  
 Ellard, H. F., on shaft at Ashland mine, 487.  
 Ellison, William Reynolds, elected member, 3.  
 Elmore, G. H., on dressing of coal, 558.  
 Emmons, S. F., on formation of ore deposits, 462.  
 Engel, *Bergmeister* Konrad, elected member, 3.  
 Engel, K., on mining property in the Ruhr coalfield, 555.  
 England, coal in, 505.  
 Engler, C., on natural gas in South Germany, 533.  
 Ensslin, on strength of circular steel plates, 672.  
 Enthoven, R. E., on mineral statistics of India, 705.  
 Eriksson magnetic separator, 492.  
 Ermisch, K., on iron ore in Germany, 465.  
 Escalas, R., book on mining by, 729.  
 Etheridge, R., on coal in England, 505.  
 Etienne, M., on coal in Asia Minor, 511.  
 Etienne, M., on iron ore in France, 485.  
 Evans, Henry Morton Glyn, elected member, 3.  
 Evans, Thomas Granger, elected member, 3.  
 Everett, J. D., on underground temperature, 538.  
 Everitt, Charles Kingston, elected member, 3.  
 Ewing, J. A., on critical ranges of iron carbon alloys, 243.  
 Ewing, J. A., on plastic yielding of iron and steel, 372.  
 Explosion in a foundry, 596.  
 Explosions of coal dust, 554.  
 Explosions of fire-damp, 488, 553.  
 Explosions produced by ferro-silicon, 30.  
 Explosives in mining, 547.  
 Eye-bars, manufacture of, 644.  
 Eyermann, P., on gas and tar as fuel, 623.  
 Eyermann, P., on utilisation of blast-furnace gas, 569.

## F.

- FABRE, L., on magnetic separation of ores, 492, 493.  
 Fabrega, P., on coal in Spain, 509.  
 Fackenthal, B. F., junr., on grading of pig iron, 580.  
 Fadrus, K., on origin of mining in Ostrau Karwin, 555.  
 Failure of lining of blast-furnace, 564.  
 Farmer, G., on underground haulage, 545.  
 Farrington, O. C., on meteorites, 484.  
 Faults, A., on mine pumps, 553.  
 Faulenbach, F., book on metallurgy by, 725.  
 Faulty boiler plates, 660.  
 Fell, E. N., on coal in Russia, 509.  
 Fenneman, N. M., on petroleum in the United States, 527.  
 Fermor, L. L., on iron ore in India, 473.  
 Ferro-manganese slag, 678.  
 Ferro-silicon, explosions produced by, 30.  
 Fèvre, L., book on mining by, 730.

- Fieber, A., on mine pumps, 552.  
 Field, H. E., on cupola practice, 588.  
 Field, H. E., on defects in cast iron, 589.  
 Fillunger, A., on rescue apparatus in mines, 557.  
 Filoleta, J., on early history of iron, 578.  
 Finance, 11.  
 Findlay, A., book on metallurgy by, 725.  
 Finland, iron ore in, 468.  
 Fire-bricks, 497.  
 Fire-damp explosions, 488, 553.  
 Fireday, 496.  
 Firmstone, F., on failure of lining of blast-furnace, 564.  
 Firmstone, F., on flue dirt and top pressure in blast-furnaces, 563.  
 Fischer's calorimeter, 501.  
 Fitzgerald, E. C., on moulding, 599.  
 Fitzgerald, F. A. J., on carborundum in the cupola, 594.  
 Fitzgerald, John Morton, elected member, 3.  
 Fixed hearth, continuous practice in a, 624.  
 Flather, Gerald Darwin, elected member, 3.  
 Fletcher, J. E., on plastic yielding of iron and steel, 373.  
 Florange, J., on French medals connected with mining and metallurgy, 579.  
 Flue dirt and top pressure in blast-furnaces, 563.  
 Fluorepar in the cupola, 595.  
 Foote, F. H., on blast-furnace practice, 578.  
 Ford, James, elected member, 3.  
 Fore-hearths to cupolas, 590.  
 Forge and mill machinery, 607.  
 Forgings, steel, 607.  
 Formation of ore deposits, 462.  
 Forsberg, G. A., on red shortness, 675.  
 Forsgren, E., magnetic separator by, 492.  
 Forster, M., book on metallurgy by, 725.  
 Foster, Sir C. Le Neve, book on mining by, 729.  
 Foster, H. Le Neve, on thermal treatment of steel, 88.  
 Foster, W. J., paper on "The thermal efficiency of the blast-furnace," 311; heat evolved, 314; losses, 316; appendix showing system adopted for estimating the value of different parts of the process, 323.—*Correspondence*: W. Hansou, 329; A. Lodin, 329; J. Parry, 330; W. J. Foster, 332.  
 Foundry appliances, 596.  
 Foundry, explosion in a, 596.  
 Foundry practice, 588.  
 Foundry practice, crucible furnace in, 592.  
 Fourmarier, P., on coal in Belgium, 506.  
 Fractional combustion, 690.  
 Frahm, J., on ore handling, 489.  
 Fraichet, L., on magnetic properties of iron, 651.  
 France, coal in, 506, 700.  
 France, iron ore in, 465.  
 France, iron trade statistics of, 699.  
 Frémont, C., on elastic limit, 648.  
 Frémont, C., on metallography, 649, 650.  
 French steelworks, 627.  
 Freudenberger, W. K., on American blast-furnace plant, 575.  
 Freund, M., on corrosion of iron and steel, 678.  
 Fryer, Tom Jefferson, elected member, 3.  
 Fuel, 501.  
 Fuel analysis, 689.

Fuel, gas and tar as, 622.  
 Fuller, M. L., on coal in the United States, 511.  
 Fuller, M. L., on petroleum in the United States, 527.  
 Furnace design, open-hearth, 618.  
 Further treatment of iron and steel, 638.  
 Fusion of malleable iron, 602.  
 Futers, T. C., on deep boring, 538.  
 Futers, T. C., on shaft sinking, 539.

## G.

GAEBLER, C., on coal in Germany, 507.  
 Galloway, C. J., obituary notice of, 447.  
 Galloway, William Johnson, M.P., elected member, 3.  
 Gartzweiler, L. C., on gas-power plant, 537.  
 Gary, M., on blast-furnace slag cement, 587.  
 Gas analysis, 690.  
 Gas and tar as fuel, 622.  
 Gas-driven rolling mills, 612.  
 Gas losses in the open-hearth furnace, 620.  
 Gas power plant, 537.  
 Gas producers; thermal reactions in, 534.  
 Gas welding and heating furnaces, 639.  
 Gases in pig iron, 581.  
 Gaster, L., on electricity in oil-fields, 533.  
 Generation and distribution of power, 614.  
 Gennes, A. de, on coal cutting, 549.  
 Georgi, M., on winding engines, 541.  
 Gerland, E., book on mining by, 729.  
 German cokes, 523.  
 Germany, canal transport in, 703.  
 Germany, coal in, 507.  
 Germany, construction of cranes in, 645.  
 Germany, iron ore in, 465.  
 Germany, iron trade statistics of, 701.  
 Germany, metallurgical education in, 703.  
 Germany, mineral statistics of, 700.  
 Germany, natural gas in, 533.  
 Germany, petroleum in, 526.  
 Gibson, T. W., on mineral statistics of Canada, 698.  
 Gilchrist, P. O., on the synthesis of Bessemer steel, 307.  
 Gillette, H. P., on formation of ore deposits, 462.  
 Gin, G., on electric production of iron alloys, 606.  
 Gin, G., on electric smelting of iron ore, 605.  
 Girty, G. H., on coal in Kansas, 512.  
 Glasgow, Earl of, speech by, 440.  
 Glasser, C. H., on converter accessories, 635.  
 Glasser, E., on iron ore in New Caledonia, 481.  
 Glasser, E., on nickel ore, 483.  
 Glazebrook, R. T., on critical ranges of iron carbon alloys, 249.  
 Glazed pig iron, 580.  
 Gledhill, J. M., on high speed tool steels, 643.  
 Gledhill, J. M., on manufacture of crucible steel, 617.  
 Gledhill, J. M., on pyrometers, 170.  
 Gledhill, J. M., on thermal treatment of steel, 76.  
 Glenn, L. C., on meteorites, 485.  
 Gobbe, on quenching coke, 517.  
 Goerens, P., on strength and structure of cast iron, 667.

- Goffe, E., on rock drills, 486.  
 Göhrum, on by-product coke, 517.  
 Goldschmidt, H., on use of thermite for castings, 641.  
 Goldstein, O., on steel production without scrap or ore, 619.  
 Gonzaga de Campos, L. F., on coal in Brazil, 513.  
 Gottlieb, J. M., on petroleum in Roumania, 526.  
 Gounot, A., on petroleum in Albania, 526.  
 Grabe, A., on determination of sulphur, 683.  
 Grades of pig iron, 580.  
 Graham, Maurice,, elected member, 3.  
 Grammer, L. F., on American blast-furnace practices, 573.  
 Grammer, F. L., on flue dirt and top pressure in blast-furnaces, 563.  
 Grammer, F. L., on hearth area and number of tuyeres, 563.  
 Grand' Eury, C., on formation of coal, 505.  
 Graphite, 498.  
 Gray, Sir E., speech by, 440.  
 Gray, F. W., on ankylostomiasis, 556.  
 Gray, G. Watson, on explosions produced by ferro-silicon, 32, 35.  
 Greaves, P. C., on coal cutting, 548.  
 Greenway ore handling machine, 489.  
 Gregory, J. W., on iron ore in Victoria, 474.  
 Grimsley, G. P., on petroleum in Kansas, 529.  
 Griswold, W. T., on petroleum in the United States, 527.  
 Grittner, A., on coal in Hungary, 508.  
 Gröndal charcoal furnaces, 573.  
 Gröndal method of briquetting ores, 495.  
 Groneman, J., on foundry appliances, 596.  
 Guardiola, R., book on mining by, 729.  
 Guarini, E., book on mining by, 729.  
 Guarini, E., on coal cutting, 549.  
 Guarini, E., on use of thermite for castings, 642.  
 Guillaume, C. E., book on metallurgy by, 725.  
 Guillet, L., on manganese steel, 657.  
 Guillet, L., on silicon steel, 659.  
 Guillet, L., on vanadium steel, 659.

## H.

- HAANEL, E., book on mining by, 729.  
 Haanel, E., on magnetic ore deposits, 486.  
 Habeta, A., book on mining by, 729.  
 Hadfield, R. A., acknowledgment of award of Bessemer Medal, 23.  
 Hadfield, R. A., member of pyrometer committee, 89.  
 Hadfield, R. A., on critical ranges of iron carbon alloys, 249, 250.  
 Hadfield, R. A., on early experiments on alloys, 579.  
 Hadfield, R. A., on pyrometers, 178.  
 Hadfield, R. A., on special iron alloys, 655.  
 Hadfield, R. A., on the synthesis of Bessemer steel, 307.  
 Hadfield, R. A., presentation of Bessemer Gold Medal to, 22.  
 Hake, C. N., on testing powder columns by X-rays, 548.  
 Haldane, J. S., on ankylostomiasis, 556.  
 Hall, J. W., book on metallurgy by, 725.  
 Hamlet, W. M., on corrosion of iron and steel, 678.  
 Hand drills in iron ore mines, 486.  
 Handling ore, 489.  
 Handling pit scrap, 625.  
 Hanson, W., on manufacture of pig iron at Herräng, 59.

- Hanson, W., on pyrometers, 173.  
 Hanson, W., on thermal efficiency of blast-furnace, 328.  
 Harbord, F. W., book on metallurgy by, 725.  
 Harbord, F. W., on explosions produced by ferro-silicon, 37.  
 Harbord, F. W., on thermal treatment of steel, 81.  
 Harbort, E., on formation of ore deposits, 463.  
 Harbort, E., on iron ores in Germany, 466.  
 Hardening of steel, 655.  
 Harker, J. A., on pyrometry, 502.  
 Harris, E. G., on mine pumps, 552.  
 Harry, David, elected member, 3.  
 Haseler, E., book on metallurgy by, 726.  
 Hatfield, W. H., on influence of casting temperature, 434.  
 Haulage at collieries, 544.  
 Hausding, A., book on mining by, 729.  
 Hawdon, W., on by-product coke, 617.  
 Hawden, W., on the Hüssener coke oven, 202.  
 Hayes, C. W., on coal in the United States, 511.  
 Hayes, C. W., on iron ore in the United States, 474.  
 Hayes, C. W., on manganese ore in the United States, 482.  
 Hayes, C. W., on petroleum in Texas, 529.  
 Hayes, C. W., on petroleum in the United States, 527.  
 Head, A. P., book on metallurgy by, 726.  
 Head, A. P., on manufacture of pig iron at Herräng, 56.  
 Hearth area and tuyeres, 563.  
 Heat treatment of steel, 653.  
 Heating furnaces, gas welding and, 639.  
 Heating pits, doors for, 641.  
 Hebb, J. A., on beehive coke, 516.  
 Hecker, on magnetic separators, 492.  
 Heim, A., on iron ore in Switzerland, 472.  
 Heinicke, F., on coal in Germany, 508.  
 Heise, F., book on mining by, 729.  
 Helps, G., on gas-power plant, 537.  
 Hepplewhite, W. H., on fire-damp detectors, 553.  
 Henin, on iron trade statistics of Russia, 711.  
 Hereza, J., on iron ore in Sweden, 472.  
 Héroult, P. L. T., on electric smelting of iron ore, 604.  
 Herräng, manufacture of pig iron from briquettes at, 40.  
 Hess, P., on explosives and blasting, 547.  
 Heurteau, C. E., on petroleum in California, 528.  
 Heyn, E., on plastic yielding of iron and steel, 375.  
 Hiby, W., on coke in the Hüssener oven, 214.  
 Hiby, W., on the Hüssener coke oven, 206.  
 High speed tool steels, 642.  
 Hildreth, P. S., on manufacture of eye-bars, 644.  
 Hill, Joseph, elected member, 4.  
 Hille, F., on iron ore in Canada, 473.  
 Himes, C. F., on an old stove plate in Susquehanna, 580.  
 Hingley, Sir B., speech by, 440.  
 Hingley, Sir B., vote of thanks to president, 260.  
 Hird, F., on electric winding engine, 541.  
 Hise, C. R. van, on Lake Superior iron ores, 476.  
 History of iron, 578.  
 Hobart, F., on electric smelting of iron ore, 603.  
 Hodgson, R. B., on Styrian steel, 579.  
 Hodorek, R., on coking brown coal, 523.



- Höfer, H., book on mining by, 729.  
 Höfer, H., on coal in Austria, 505.  
 Hoffman, F. L., on accidents in collieries in the United States, 719.  
 Hoffmann, R., on coking brown coal, 522.  
 Holde, D., on chemistry of petroleum, 524.  
 Holland, coal in, 704.  
 Holland, Job, elected member, 4.  
 Hollis, H. W., obituary notice of, 448.  
 Holm, E., on mineralogical characteristics of iron ore, 464.  
 Holobek, J., on fire-damp explosion in ozokerite mines, 525.  
 Holz, on iron trade statistics of Russia, 708.  
 Holz, F., on high speed tool steels, 644.  
 Honduras, coal in, 514.  
 Hopkins, T. C., on iron ores in Pennsylvania, 478.  
 Hörhager, J., book on mining by, 729.  
 Hörhager, J., on metallurgical education in Germany, 704.  
 Horsley, G. F., on determination of silicon, 681.  
 Howard, J. E., on metallography, 650.  
 Howard, J. E., on tensile and repeated stress, 662.  
 Howe, H. M., on crystallisation of iron, 647.  
 Howley, J. P., on mining industry of Newfoundland, 698.  
 Hoyt, C. H., on beehive coke, 516.  
 Huber, H., book on metallurgy by, 726.  
 Huber, S. V., on American rolling mill plant, 610.  
 Hubers, J., on continental rolling mill plant, 609.  
 Hudson, O. F., on glazed pig iron, 580.  
 Hughes, Herbert, elected member, 4.  
 Hughes, H. W., book on mining by, 729.  
 Hulme, James, elected member, 4.  
 Hungary, coal-mining in, 696.  
 Hunter, John, elected member, 4.  
 Hüssener oven, manufacture of coke in, at Clarence ironworks, 188.  
 Hutin, Edmond, elected member, 4.

## I.

- IBORSON, J. G. P., book on mining by, 729.  
 Idaho, petroleum in, 528.  
 Ihering, A. von, on brown coal producer-gas, 538.  
 Ilgner, C., on electric power in the rolling mills, 613.  
 Improvements in ore dressing, 490.  
 Improvements in quenching coke, 516.  
 India, coal in, 510.  
 India, iron ore in, 473.  
 India, manganese ore in, 482.  
 India, mineral statistics of, 705.  
 India, petroleum in, 527.  
 Indian steel, historical references to, 578.  
 Indo-China, mineral resources of, 698.  
 Influence of casting temperatures, 420.  
 Ingleby, J., on coke in the Hüssener oven, 222.  
 Ingots, preventing blowholes in, 641.  
 Ingots, sound, production of, 638.  
 Invitation to New York, 12.  
 Iowa, coal in, 512.  
 Ireland, W. G., on determination of sulphur, 683.  
 Irmeler, A., on iron ore in Austria, 465.

Iron alloys, electric production of, 605.  
 Iron alloys, special, 655.  
 Iron and steel, analysis of, 680.  
 Iron and steel, further treatment of, 638.  
 Iron and steel, plastic yielding of, 335.  
 Iron, atomic weight of, 675.  
 Iron, corrosion of, 676.  
 Iron, crystallisation of, 647.  
 Iron, determination of, 688.  
 Iron, effect of repeated heating of, 654.  
 Iron, loss of, in the cupola, 589.  
 Iron, loss of, in the reverberatory furnace, 593.  
 Iron, magnetic properties of, 651.  
 Iron ore, electric smelting of, 603.  
 Iron ore mining, 486.  
 Iron ores, 462.  
 Iron ores and slag, analysis of, 687.  
 Iron props for mine supports, 545.  
 Iron smelting, native, 602.  
 Ironwork, structural, 645.  
 Ironworks, analysis, 680.  
 Irresberger, C., on crucible furnace in foundry practice, 592.  
 Italy, coal in, 508.  
 Italy, petroleum in, 526.  
 Ivanoff, M., book on mining by, 731.  
 Iyer, V. S. Sambasiva, on iron ore in India, 473.

## J.

JACKSON, Ernest Wilfrid, elected member, 4.  
 Jacobs, on coal in Canada, 510.  
 Jaquet, J. B., on fire-damp explosion in iron mine, 488.  
 Jaer, J. de, on mineral statistics of Belgium, 696.  
 James, E., on Hüssener coke oven, 209.  
 James, E., on pyrometers, 172.  
 Janke, on wrought iron and cast iron pipes, 673.  
 Janssen, F., on electric power in the rolling mills, 614.  
 Japan, mineral statistics of, 706.  
 Jenkins, H. C., on underground temperatures, 538.  
 Job, R., on specifications for cast iron, 672.  
 Johansson, A., on small converters, 632.  
 John, C. von, on calorific value of coal, 501.  
 Johns, C., *paper* on "The production and thermal treatment of steel in large masses," 61; introductory, 61; casting, 64; forging and rolling, 65; tires, 66; axles, 67; shafts, 68; oil hardening, 71; vibratory tests, 72; conclusion, 73.—*Discussion*: W. F. Beardshaw, 75; J. M. Gledhill, 76; F. W. Harbord, 81; A. McWilliam, 82; F. J. R. Carulla, 84; C. Johns, 85.—*Correspondence*: R. M. Daelen, 87; H. Le Neve Foster, 88; J. Parry, 89; A. W. Richards, 89; R. G. Scott, 90; J. E. Stead, 92; C. Johns, 93.  
 Johns, C., on synthesis of Bessemer steel, 308.  
 Johnson, Elias M., elected member, 4.  
 Johnson, G., on comparative mineral statistics, 722.  
 Johnson, J. E., jr., on oxygen and sulphur in cast iron, 675.  
 Jones, E., obituary notice of, 448.  
 Judson, J. N., on magnetic separators, 495.  
 Jüptner von Jonstorff, Baron H., on water gas, 537.  
 Jürgensen, on by-products from charcoal burning, 516.  
 Justice, J. N., on deep boring, 538.

1904—1.

3 B

## K.

- KAISER, on bauxite, 498.  
 Kaleczinsky, A. von, book on mining by, 729.  
 Kaleczinsky, A. von, on coal in Hungary, 508, 696.  
 Kanitz, J., on petroleum in Roumania, 707.  
 Kansas, coal in, 512.  
 Kansas, natural gas in, 534.  
 Kansas, petroleum in, 529.  
 Karkeet, J. H., on explosives in mines, 547.  
 Katona, L., on tests of metals, 668.  
 Katzer, F., on iron ore in Bosnia, 464.  
 Katzer, F., on iron ore on the Lower Amazon, 481.  
 Kearna, Henry Ward, elected member, 4.  
 Keeling, Bertram F. E., elected member, 4.  
 Keeling, B. F. E., *see* Carpenter, H. C. H.  
 Kegel, on brown coal producer-gas, 538.  
 Keiser & Schmidt's electrical pyrometer, 503.  
 Keith, A., on iron ore in North Carolina, 478.  
 Keith, A., on iron ore in the United States, 474.  
 Kemp, J. F., on formation of ore deposits, 462.  
 Kennard, R. W., elected member, 4.  
 Kennedy, W., on petroleum in Texas, 529.  
 Kershaw, J. B. C., on calorific value of coal, 502.  
 Kershaw, J. B. C., on electric smelting of iron ore, 603.  
 Kessler, J. J., jun., on metallography, 651.  
 Kiao-chou, coal at, 699.  
 Kieslinger, F., book on mining by, 730.  
 Kind-Chaudron sinking at Dover, 539.  
 King, H. S., on coal in Western Australia, 511.  
 Kingsbury, A., on roller-driven tables, 609.  
 Kirchberg, E., on design of rolls, 607.  
 Kirk, Thomas, jun., elected member, 4.  
 Kirkpatrick, W. P., on coke in the Hüssener oven, 214.  
 Kissling, E., book on mining by, 730.  
 Kissling, R., on chemistry of petroleum, 524.  
 Kjellin, F. A., on electric smelting of iron ore, 604.  
 Kleine, A., on ironworks analysis, 680.  
 Klockmann, F., on formation of ore deposits, 463.  
 Klöse, on shaft sinking, 539.  
 Knight, S. S., on determination of sulphur, 683.  
 Knorre, G. von, on determination of manganese, 682.  
 Knüsel, T., on analysis of basic slag, 689.  
 Knox, L. L., on open-hearth furnace design, 618.  
 Knox, L. L., on steel castings, 641.  
 Koehler, H., book on mining by, 730.  
 Koehler, W., *report* on lighting of collieries, 554.  
 Koepe winding system, 542.  
 Kohl, M., on calorimetry, 501.  
 Kohler, E., on coal in Germany, 507.  
 Kohlmann, W., on iron ores in Luxemburg, 467.  
 Kohser, O., on accidents in collieries in the United States, 719.  
 Köndgen, on mine surveying, 555.  
 Koninck, L. de, on determination of iron, 688.  
 Körting gas producer, 536, 570.  
 Kottgen, C., on electric power in the rolling mills, 614.

- Kramers and Clarte' water gas system, 537.  
 Krepelka, V., on asphalt, 532.  
 Kretschmer, F., on graphite, 498.  
 Kretschmer, F., on iron ore in Austria, 464.  
 Krizko, B., on coal in Hungary, 508.  
 Kroeker, K., on thermal reactions in the gas producer, 534.  
 Kroupa, G., on determination of sulphur, 689.  
 Kubling, O., on determination of iron, 688.  
 Kuklin, E., on determination of tungsten, 684.  
 Kunz, R., on valves used in American blast-furnace practice, 577.  
 Künzel, on faulty boiler plates, 661.  
 Küppers, W., on charging machines, 626.  
 Kuss, H., book on mining by, 730.  
 Kuss, H., on over-winding appliances, 543.  
 Kuwadi, G., on high speed tool steels, 644.  
 Kuwadi, G., on manufacture of projectiles, 646.

## L.

- LACANNE, Félix, elected member, 4.  
 Lake Superior iron ores, 475.  
 Lakes, A., on asphalt, 532.  
 Lambert, Thomas, elected member, 4.  
 Lamberton, A., vote of thanks by, 21.  
 Lamoureux, E., on construction of modern blast-furnace, 562.  
 Landes, H., book on mining by, 730.  
 Landes, H., on coal in Washington, 513.  
 Langton, J., on gas producers, 535.  
 Långqvist, Orvar, elected member, 4.  
 Larke, William James, elected member, 4.  
 Lauder, T. H., on doors for heating pits, 641.  
 Lauer, J. von, on safety shot-firing, 548.  
 Launay, L. de, book on mining by, 730.  
 Launay, L. de, on concentration of Swedish ores, 492.  
 Launay, L. de, on formation of ore deposits, 463.  
 Launay, L. de, on iron ore in Sweden, 472.  
 Laveleye, E. de, on steelworks in Belgium, 697.  
 Laverick, John H. W., elected member, 4.  
 Lavino, E. J., elected member, 4.  
 Lazar, P., on iron industry of America, 717.  
 Lazurtegui, J. de, books on metallurgy by, 726.  
 Lazurtegui, J. de, on iron ore in West Cumberland, 464.  
 Leach, C. C., on superheated steam at collieries, 541.  
 Leavitt, T. H., book on mining by, 730.  
 Le Chatelier, Henry Louis, elected member, 4.  
 Le Chatelier, H., on brittleness of steel, 655.  
 Le Chatelier, H., on cement from blast-furnace slag, 587.  
 Le Chatelier, H., on critical ranges of iron carbon alloys, 246.  
 Le Chatelier, H., on explosions produced by ferro-silicon, 38.  
 Le Chatelier, H., on pyrometers, 161.  
 Le Chatelier, H., on troostite, 290.  
 Le Chatelier, H., speech by, at dinner, 441.  
 Le Chatelier pyrometer, 106, 503.  
 Leckie, R. G., on nickel ore, 483.  
 Leclère, A., on determination of iron, 689.  
 Lecocq, E., on determination of carbon, 681.  
 Ledebur, A., book on metallurgy by, 726.

- Ledebur, A., bust of, presented to Institute, 15.  
 Ledebur, A., on manganese steel, 658.  
 Ledebur, A., on metallurgical education in Germany, 704.  
 Lees, John, elected member, 4.  
 Lehmann, on Riedler pumps, 552.  
 Leith, C. K., on iron ore in the United States, 474.  
 Lemoine, A., on brown coal briquettes, 561.  
 Lengemann, on metallurgical education in Germany, 703.  
 Lenicque, H., book on mining by, 730.  
 Lenz, W., on mine surveying, 555.  
 Leroyer, L., on electric welding, 642.  
 Leu, E., book on metallurgy by, 726.  
 Levat, E. D., on petroleum in Russia, 526.  
 Lewes, V., on water gas, 537.  
 Leyde, O., on foundry appliances, 597.  
 Leyde, O., on strength and structure of cast iron, 666.  
 Leyde, O., on testing cast iron, 664.  
 Library, additions to, 15, 453.  
 Lidholm, H., on determination of silicon, 681.  
 Lidl, J. von, on winding engines, 542.  
 Lighting of collieries, 554.  
 Limestone in the cupola, 594.  
 Lindley, C. H., book on mining by, 730.  
 Lindow, J., obituary notice of, 448.  
 Lining of blast-furnace, failure of, 564.  
 Linse, W., on structural ironwork, 645.  
 Liquid fuel, 524, 533.  
 Liversidge, A., on meteorites, 484.  
 Lloyd, M. B., on explosions of ferro-silicon. *See* Dupré, A.  
 Lodin, A., book on metallurgy by, 726.  
 Lodin, A., on thermal efficiency of blast-furnace, 329.  
 Lofty buildings, use of steel in, 391.  
 Lomnitz, H., book on metallurgy by, 726.  
 Longden, Alfred Henry, elected member, 4.  
 Longmuir, P., *paper* on "The influence of varying temperature on the properties of steel and iron," 420; introductory, 420; cast and malleable iron, 421; steel castings, 423; microscopical, 430; practical consideration, 432.—*Correspondence*: W. H. Hatfield, 434; A. McWilliam, 435; J. Parry, 436; P. Longmuir, 436.  
 Loomis-Pettibone gas producers, 535.  
 Lopez, F. O., on petroleum in Peru, 530.  
 Loss of iron in the cupola, 589.  
 Loss of iron in the reverberatory furnace, 593.  
 Lotti, A., on fluor spar in the cupola, 595.  
 Louis, D. A., on methods of working in mines, 551.  
 Louis, D. A., on pithead gear at Neumuhl, 543.  
 Louis, H., on asphalt, 532.  
 Louis, H., on magnetic ore deposits, 486.  
 Louis, H., on pyrometers, 166.  
 Louis, H., *paper* on "The manufacture of pig iron from briquettes at Herräng," 40; description of locality, 40; nature of the ores, 41; historical review, 41; scheme of operations, 42; mines, 43; concentrating works, 44; briquetting plant, 47; chemical composition of concentrates, 47; briquetting plant, 47; analysis of briquettes, 49; blast-furnace plant, 50; limestone used, 51; composition of pig iron and slag made, 52; conclusions, 53; analyses of ores, 55.—*Discussion*: A. P. Head, 56; A. Weiskopf, 57; H. Louis, 58.—*Correspondence*: W. Hansen, 59; J. E. Stead, 60.  
 Louisiana, petroleum in, 530.

- Low, S., speech by, at annual dinner, 440.  
 Lowman, W. B., on American open-hearth steel plants, 630.  
 Lozé, E., on briquettes, 560.  
 Ludlow, E., on mineral industry of Mexico, 706.  
 Lunge, G., on asphalt, 532.  
 Lürmann, F. W., jun., on thermal reactions in the gas-producer, 534.  
 Luttermann, on winding-rope stresses, 544.  
 Luty, B. E. V., on American rolling-mill plant, 610.  
 Luxemburg, iron ores in, 467.  
 Luxemburg, mineral statistics of, 703.  
 Lynch, T. D., on steel forgings, 607.

## M.

- Macaulay, J., on coal storage, 515.  
 Mucco, A., on open cast working, 487.  
 Mucco, H., on American open-hearth steel plants, 629.  
 Mucco, H., on the Edgar Thomson blast-furnaces, 576.  
 Mucco, H., on Lake Superior iron ores, 476.  
 M'Farlane, William, elected member, 4.  
 Macfarlane, W., on history of iron, 578.  
 MacGeorge deep boring instrument, 538.  
 Machacek, K., on gas engines for blast-furnaces, 570.  
 Mackay, Harry J. Sutherland, elected member, 4.  
 Mackay-Heriot, E., on iron ore in Spain, 468.  
 McKee, G. W., mineralogical characteristics of iron ore, 463.  
 McMillan, W. G., obituary notice of, 448.  
 McWilliam, A., on critical ranges of iron carbon alloys, 250.  
 McWilliam, A., on influence of casting temperature, 435.  
 McWilliam, A., on pyrometers, 162.  
 McWilliam, A., on thermal treatment of steel, 82.  
 Magnesite, 498.  
 Magnetic ore deposits, 486.  
 Magnetic properties of iron, 651.  
 Magnetic separators, 492.  
 Mahler's calorimeter, 504.  
 Malette, J., on determination of manganese, 682.  
 Malissard-Taza, P., on mining machinery, 541.  
 Mallada, L., on coal in Spain, 510.  
 Malleable castings, 599.  
 Malleable iron, carburisation of, 617.  
 Malleable iron, fusion of, 602.  
 Malleable iron, production of, 602.  
 Mallmann, P. J., on by-product coke, 517.  
 Manganese, determination of, 682.  
 Manganese ore, 481.  
 Manganese ore in the cupola, 594.  
 Manganese steel, 667.  
 Mansfield, N., on tube rolling, 615.  
 Manufacture of coke in the Hüssener oven at Clarence ironworks, 188.  
 Manufacture of crucible steel, 617.  
 Manufacture of eye-bars, 644.  
 Manufacture of pig iron from briquettes at Herräng, 40.  
 Manufacture of projectiles, 646.  
 Manufacture of tin-plates, 646.  
 Marburg, E., on standard specifications, 672.

- Marcette, A., on shaft sinking, 539.  
Marks, E. C. R., on tube rolling, 616.  
Marshall, Charles Cecil, elected member, 4.  
Martin, on Mond gas, 537.  
Martin, Hugh, elected member, 4.  
Martin, John, elected member, 5.  
Massart, G., book on mining by, 731.  
Masterman, C. E., on use of thermite for castings, 642  
Mather, W. G., on charcoal blast-furnaces, 564.  
Mathews, John Alexander, elected member, 5.  
Mathias, E., book on metallurgy by, 726  
Mauerhofer, J., on methods of working in mines, 549.  
Mauerhofer, J., on sanitation in collieries, 557.  
Maurain, C., on magnetic properties of iron, 651.  
May, W. J., on coke for foundry use, 589.  
Mechan, Arthur, elected member, 5.  
Mechanical preparation of ores, 490.  
Medals and research scholarships, 15.  
Medals relating to the iron industry, 579.  
Meine's stratameter, 538.  
Melhuish, Richard, elected member, 5.  
Mennie, J. S., sanitation at mines, 489.  
Mentzel, H., on petroleum in Austria, 524, 525.  
Mercer, H., on old specimens of American iron work, 580.  
Merrett, William Henry, elected member, 5.  
Merrill, G. P., book on mining by, 730.  
Messerschmitt, J. B., on mine surveying, 555.  
Mesuré and Nouel optical pyrometer, 110.  
Metals, semi-fluid state of, 647.  
Metals, steel hardening, 718.  
Metals, test of, 668.  
Metallography, 649.  
Metallurgical preparation, 490.  
Metcalf, W., on hardening of steel, 655.  
Meteorites, recent researches on, 484.  
Methods of working in collieries, 549.  
Meurice, A., on coal analysis, 690.  
Mexico, coal in, 513.  
Mexico, mineral industry of, 706.  
Michaelis, S., on coal in South Africa, 510.  
Michall, R., on coal in Germany, 508.  
Middendorf, on mine supports, 545.  
Miller, E. H., book on mining by, 730.  
Minard, F. H., on asphalt, 532.  
Mine drainage, 551.  
Mine supports, 545.  
Mine surveying, 555.  
Mineralogical characteristics of iron ore, 463.  
Miners' phthisis, 556.  
Miners' wages, 723.  
Minette, analysis of, 687.  
Mingay, J. C. H., on meteorites, 484.  
Mingay, J. C. H., on vanadium in coal, 515.  
Mining of iron ore, 486.  
Minnesota, ore mining in, 488.  
Misfires, 548.  
Missouri, petroleum in, 529.

- Mitchell, T., book on mining by, 730.  
 Mitchell, T., on history of Monmouthshire iron trade, 578.  
 Mittasch, A., on determination of manganese, 682.  
 Mixed Bessemer and open-hearth process, 637.  
 Modern coke oven plant, 520.  
 Mohring, R., book on metallurgy by, 726.  
 Moldenke, R., on foundry appliances, 596.  
 Moldenke, R., on oxygen and sulphur in cast iron, 675.  
 Moldenke, R., on specifications for cast iron, 672.  
 Moldenke, R., on testing cast iron, 665.  
 Möller, P., on cold working of steel, 640.  
 Molybdenite, 484.  
 Mond gas, 537.  
 Mourad, A. L., on testing machines, 662.  
 Montana, coal in, 512.  
 Moorwood, Hedley Stanley, elected member, 5.  
 Morgan, John, elected member, 5.  
 Morton, D. A., on determination of sulphur, 689.  
 Morse pyrometer, 504.  
 Moser, L. K., on manganese ore in Austria, 481.  
 Moses, Moses, elected member, 5.  
 Moss, C. E., on peat, 514.  
 Mostaccio, L., book on mining by, 730.  
 Motive power from blast-furnace gas, 568.  
 Mott, Samuel Thornley, elected member, 5.  
 Moulding, 598.  
 Mount-Haes, A., elected member, 5.  
 Mrazec, L., on iron ore in Russia, 467.  
 Muhlen, F. zur, on coal in Hungary, 508.  
 Müffelmann, L., on petroleum in Germany, 526.  
 Müller, on basic Bessemer slag, 636.  
 Müller, A., on coal washing, 558.  
 Müller, Gustav, elected member, 5.  
 Müller, G., on petroleum in Germany, 526.  
 Müller-Landsmann, J. R., book on mining by, 730.  
 Mumford, W. E., on additions in the open-hearth process, 621.  
 Munker, E., on gases in pig iron, 581.  
 Muras, Robert, elected member, 5.  
 Murphy, B. S., book on metallurgy by, 726.  
 Mysore, mineral statistics of, 706.

## N.

- NAGEL, O., on acid-proof castings, 595.  
 Nagel, O., on water gas, 536.  
 Naske, T., on iron trade statistics of Russia, 708.  
 Native iron smelting, 602.  
 Natural gas, 533.  
 Nau, J. B., on blast-furnace practice, 578.  
 Nau, J. B., on calculations of blast-furnace burdens, 583.  
 Nelson, Andrews Selanders, elected member, 5.  
 Neuberg, E., on gas engines for blast-furnaces, 570.  
 Neuburger, A., on electric smelting of iron ore, 604.  
 Neumann, B., book on metallurgy by, 726.  
 Neumann, B., on history of iron, 578.  
 Neumann, B., on nickel and cobalt ores, 483.



- Neumann, B., on world's production of pig iron, 722.  
 Neumann, B., on world's production of steel, 722.  
 Neville, F. H., on plastic yielding of iron and steel, 379.  
 New Caledonia, iron ore in, 481.  
 New South Wales, iron ore in, 474.  
 New York, invitation to, 12.  
 New York, iron ore in, 477.  
 New York, ore mining in, 488.  
 Newfoundland, mining industry of, 698.  
 Nicholson, J. T., book on metallurgy by, 726.  
 Nickel ores, 483.  
 Nickel steel, 659.  
 Nieszner, J., on asphalt, 532.  
 Niollet, H., on working thin seams, 551.  
 Nisbet, D. F., on comparison of small and large mill plant, 609.  
 Noake, Frank, elected member, 5.  
 Nopcsa, F., on coal in Hungary, 508.  
 Nordenström, G., on magnetic ore deposits, 486.  
 Norris, R. V., on electric haulage plant, 545.  
 North Carolina, iron ore in, 478.  
 North Staffordshire, iron ore in, 464.  
 Norton, C. L., on corrosion of iron and steel, 676.  
 Norway, iron ores in, 467.  
 Norway, mineral statistics of, 707.  
 Novarese, V., on asphalt, 530.  
 Novarese, V., on formation of ore deposits, 463.

## O.

- OBITUARY, 446.  
 Obst, on slime packings for waste workings in mines, 550.  
 Occurrence of iron ores, 462.  
 Odelstjerna, E. G., on Swedish blast-furnace practice, 573.  
 Oellerich, on calorific value of coal, 502.  
 Ohly, J., on special iron alloys, 656.  
 Oil-fuel burners, 533.  
 Oil shale, 530.  
 Oldham, R. D., on petroleum in India, 527.  
 Oliphant, F. H., on natural gas in United States, 719.  
 Oliver mine, winding plant at, 487.  
 Open cast working, 486.  
 Open-hearth furnace designs, 618.  
 Open-hearth furnace, gas losses in the, 620.  
 Open-hearth process, 618.  
 Open-hearth process, additions in the, 621.  
 Open-hearth process, mixed Bessemer and, 637.  
 Open-hearth steel, basic, 623.  
 Open-hearth steel plants, American, 629.  
 Open-hearths, small, for castings, 626.  
 Ore concentration, 490.  
 Ore deposits, formation of, 462.  
 Ore dressing, 490.  
 Ore drying at blast-furnaces, 578.  
 Ore handling, 489.  
 Ore, mechanical preparation of, 490.  
 Ore mining, 486.

Ores, mineralogical characteristics of iron, 463.  
 Osborn, C. S., on iron ore in Sweden, 472.  
 Osborn, Frederick Marmaduke, elected member, 5.  
 Osmond, F., book on metallurgy by, 727.  
 Osmond, F., on critical ranges of iron carbon alloys, 253.  
 Osmond, F., on metallography, 649, 650.  
 Osmond, F., on troostite, 288.  
 Otto, H., on faulty boiler plates, 660.  
 Outerbridge, A. E., jun., on effect of repeated heating of iron and steel, 654.  
 Outhwaite, Harry, elected member, 5.  
 Overwinding, appliances for preventing, 543.  
 Oxygen and sulphur in cast iron, 675.  
 Ozokerite in Galicia, 525.

## P.

PAINTER, A., on ore handling, 490.  
 Parlee, on rock drills, 486.  
 Parrington, T. E., on balance ropes, 543.  
 Parr's method of calorimetry, 501.  
 Parry, J., on coke in the Hüssener oven, 222.  
 Parry, J., on critical ranges of iron carbon alloys, 255.  
 Parry, J., on explosions produced by ferro-silicon, 39.  
 Parry, J., on influence of casting temperature, 436.  
 Parry, J., on plastic yielding of iron and steel, 390.  
 Parry, J., on thermal efficiency of blast-furnace, 330.  
 Parry, J., on thermal treatment of steel, 89.  
 Parsons, H. de B., book on metallurgy by, 727.  
 Patents, list of British, for pyrometers, 147.  
 Patterson, A., on pyrometers, 179.  
 Pavloff, M. A., book on metallurgy by, 727.  
 Pavloff, M. A., on Russian steelworks, 628.  
 Paz-Soldan, F. A. y, on coal in Peru, 513.  
 Peacock, Tom Swift, elected member, 5.  
 Pears, G., obituary notice of, 449.  
 Pearce, J. W., on iron ores in Luxemburg, 467.  
 Pearson, H. W., obituary notice of, 449.  
 Pearson, William Henry, elected member, 5.  
 Peat, 514.  
 Pehrson, Alfred Petter, elected member, 5.  
 Pellati, N., on coal in Italy, 509.  
 Pelli, P., on pyrometers, 180.  
 Pendlebury, C., on high speed tool steels, 643.  
 Pennoek, J. D., on determination of sulphur, 689.  
 Pennsylvania, iron ore in, 478.  
 Perkins, F. C., on electric smelting of iron ore, 605.  
 Pernia, petroleum in, 527.  
 Peru, coal in, 513.  
 Peru, petroleum in, 530.  
 Pestell, W., on rails, 644.  
 Petersson, W., on concentration of Swedish ores, 490.  
 Petersson, W., on iron ore in Sweden, 469.  
 Petroff, A., on coal in Russia, 509.  
 Petroleum, origin of, 524.  
 Pettit, Walter Richard, elected member, 5.  
 Pfeiffer, O., on determination of sulphur, 690.  
 Physical properties, 647.  
 Physics of cast iron, 663.

- Piccioli, Arturo, elected member, 5.  
 Pierson gas-producer, 536.  
 Pietrusky, P., on iron industry of the United States, 717.  
 Pig iron, gases in, 581.  
 Pig iron, manufacture of, from briquettes, at Herräng, 40.  
 Pig iron, production of, 562.  
 Pintsch gas-producer, 536.  
 Pipes, wrought iron and cast iron, 673.  
 Pit scrap, handling, 625.  
 Pittman, E. F., on iron ore in New South Wales, 474.  
 Plastic yielding of iron and steel, 335.  
 Podrowzek, A., on origin of mining in Ostrau-Karwin, 555.  
 Pohl, A., on the Schröder kiln, 497.  
 Pohlig, J., on coal handling appliances, 559.  
 Ponthière, H., book on metallurgy by, 727.  
 Popplewell, W. C., on elastic limit, 648.  
 Porter, J. J., on zinc in the blast-furnace, 584.  
 Portland cement from blast-furnace slag, 587.  
 Portraits, addition to collection of, 15.  
 Portugal, mineral statistics of, 707.  
 Poussigue, L., on shaft sinking, 539.  
 Powelson, W. V. N., on shaft sinking, 540.  
 Power, generation and distribution of, 614.  
 Prein, on shaft sinking, 540.  
 President, *see* Carnegie, A.  
 Preventing blowholes in ingots and castings, 641.  
 Primrose, A., on iron ore in India, 473.  
 Probert, R. H., on manufacture of crucible steel, 617.  
 Producer-gas from brown coal, 538.  
 Production of iron alloys, electric, 605.  
 Production of malleable iron, 602.  
 Production of pig iron, 562.  
 Production of sound ingots, 638.  
 Production of steel, 617.  
 Projectiles, manufacture of, 646.  
 Prudhomme, J., on coal handling appliances, 559.  
 Puddling, 602.  
 Puissant, J., on open-hearth furnace design, 618.  
 Pump for ironworks, 568.  
 Pumps used in mine drainage, 551.  
 Pyrometers, suitable for metallurgical work, 89; *report* on, 98; Baird and Tatlock pyrometer, 99; Bristol's recording air pyrometer, 101; Callender and Griffith's thermometers, 103; Le Chatelier pyrometer, 106; Mesuré and Nouel optical pyrometer, 110; Roberts-Austen recording electric pyrometer, 112; Rosenhain-Chalmers optical pyrometer, 115; Seger cones, 116; Siemens electric pyrometer, 118; Uehling recording pyrometer, 124; Wanner optical pyrometer, 140; Zaubitz pyrometer, 147; list of British patents for pyrometers, 147; bibliography, 154.—*Discussion*: J. E. Stead, 160; H. Le Chatelier, 161; A. McWilliam, 162; A. Campion, 165; H. Louis, 166; T. Turner, 167; J. M. Gledhill, 170; B. H. Thwaite, 174; E. James, 172; W. Hanson, 176; Sir L. Bell, 174; W. Rosenhain, 174; J. O. Arnold, 177; R. A. Hadfield, 178.—*Correspondence*: A. Patterson, 179; P. Pellin, 180; A. Sahlin, 181; A. Weiskopf, 185.  
 Pyrometry, 502.

## Q.

- QUEENSLAND, mineral statistics of, 694.  
 Quenching ooze, improvements in, 516.  
 Quest, W. O., on steel waggons, 645.

## B.

- RABE, H., on pyrometry, 502.  
 Raemdonck, A. van, on coal in Holland, 704.  
 Rails, 644, 673.  
 Reboud, A., book on mining by, 730.  
 Recent researches on meteorites, 484.  
 Redding, Richard James, elected member, 6.  
 Redmayne, R. A. S., on coal in the United Kingdom, 693.  
 Red shortness, 675.  
 Rees, William David, elected member, 6.  
 Rees, William John, elected member, 6.  
 Refractory materials, 496.  
 Relation between stresses slowly and stresses suddenly applied to iron and steel, 413.  
 Renier, A., on coal in Belgium, 506.  
 Repeated heating of iron and steel, effect of, 654.  
 Repeated stress, tensile and, 662.  
 Report of Council, 9.  
 Report of Treasurer, 17.  
 Reusch, Paul, elected member, 6.  
 Reusch, P., on manganese ore in the supola, 594.  
 Reusch, P., on testing cast iron, 665.  
 Reverberatory furnace, loss of iron in the, 593.  
 Rhodes, Charles J., elected member, 6.  
 Richards, A. W., on thermal treatment of steel, 89.  
 Richards, Joseph William, elected member, 6.  
 Richards, R. H., on magnetic separators, 492.  
 Richards, William, elected member, 6.  
 Richter, on electrical plant in mines, 547.  
 Richter, R., on magnetic properties of iron, 651.  
 Rickard, T. A., book on mining by, 730.  
 Rideal, S., on coke in the Hüssener oven, 212.  
 Ridsdale, C. H., on the plastic yielding of iron and steel, 382.  
 Riedler pumps, 552.  
 Riemer, J., on production of sound ingots, 638.  
 Ries, H., book on mining by, 731.  
 Ries, H., on fire-bricks, 497.  
 Riffe, F., on tube rolling, 616.  
 Riley, J., on the Hüssener coke oven, 205.  
 Rinne, H., on corrosion of iron and steel, 676.  
 Robertson, E. H., on limits of deep boring, 543.  
 Robertson, E. H., on mining machinery, 546.  
 Roberts, P., book on mining by, 731.  
 Roberts-Austen recording electric pyrometer, 112.  
 Robinson, T. W., on blast-furnace practice, 578.  
 Rock drills in iron ore mines, 486.  
 Rodde, on winding engine trials, 541.  
 Rohn, O., on iron ore in Wisconsin, 480.  
 Rohrbach, P., on petroleum in Persia, 527.  
 Rolin, H., book on mining by, 731.  
 Roll of the Institute, 9.  
 Rollason, A., on generation and distribution of power, 614.  
 Roller-driven tables, 609.  
 Rolling mill engines, 614.  
 Rolling mill plant, American, 610.  
 Rolling mill plant, continental, 609.

- Rolling mills, electric power in the, 613.  
 Rolling mills, gas-driven, 612.  
 Rolls, design of, 607.  
 Roozeboom, H. W. Bakhuys-, on critical ranges of iron carbon alloys, 257.  
 Rose, T. K., on critical ranges of iron carbon alloys, 256.  
 Rosenhain, W., *paper* on "The plastic yielding of iron and steel," 335; fundamental phenomena, 335; true physical character of minute surface inequalities, 340; crystalline nature of the deformations, 341; character of the slip-bands, 343; arguments against the slip-bands theory, 349; appearances to be observed on repolishing and etching strained iron, 356; mechanism of cohesion between adjacent crystalline grains, 358; summary of results, 367; list of photomicrographs, 370.—*Correspondence*, J. A. Ewing, 372; J. E. Fletcher, 373; E. Heyn, 375; F. H. Neville, 379; J. Parry, 380; C. H. Ridsdale, 382; W. Rosenhain, 385.  
 Rosenhain, W., on pyrometers, 174.  
 Rosenhain-Chalmers optical pyrometer, 115.  
 Rosset, J., on coal cutting, 549.  
 Rossi, A. J., on electric production of iron alloys, 605.  
 Rothkegel, on mine surveying, 555.  
 Rott, C., on small converters, 634.  
 Roumania, petroleum in, 526, 707.  
 Rowe, J. P., on coal in Montana, 512.  
 Ruddy, C. A., book on mining by, 730.  
 Ruddy, C. A., on coal in Washington, 513.  
 Ruhl, Louis, elected member, 6.  
 Rumin, W., book on mining by, 731.  
 Rupprecht, H., on construction of cranes in Germany, 645.  
 Rupprecht, H., on ore handling, 489.  
 Rushmer, on high speed tool steels, 643.  
 Russell, I. C., on petroleum in Idaho, 528.  
 Russia, coal in, 509.  
 Russia, iron ore in, 467.  
 Russia, iron trade statistics of, 708.  
 Russia, petroleum in, 526, 712.  
 Russian steelworks, 628.  
 Ruthenburg, M., on electric smelting of iron ore, 604.  
 Ryba, G., on safety appliances for winding, 543.

## S.

- SACHS, A., on formation of ore deposits, 463.  
 Safety brakes at collieries, 543.  
 Sahlin, A., on pyrometers, 181.  
 Sahlin, A., on slags as paint stock, 586.  
 Sainte-Claire Deville, on coal in France, 507.  
 Saladin, E., on determination of critical points, 652.  
 Samuelson, F. A. E., on the Hüssener coke oven, 205.  
 Sanders, W. E., on shaft sinking, 540.  
 Sanitation at ore mines, 489.  
 Sanitation in collieries, 556.  
 Sattmann, A., on design of rolls, 608.  
 Sattmann, A., on Stäpf continuous blast-furnace, 565.  
 Sauveur, Albert, elected member, 6.  
 Sauveur, A., on metallography, 650.  
 Schaefer, J. V., on coal washing plant, 558.  
 Scheele, A., on ventilation of collieries, 553.  
 Scherenberg, E., on generation and distribution of power, 614.  
 Schmatolla, E., on thermal balance of a crucible steel furnace, 618.

- Schmerber, H., on underground haulage, 544.  
 Schmidt, A., on iron ore in Germany, 466.  
 Schmitz, on tensile tests of mild steel, 669.  
 Schnabel, C., book on metallurgy by, 727.  
 Schnelle, F. O., book on mining by, 731.  
 Schorr, R., on briquettes, 560.  
 Schorr, R., on briquetting, 495.  
 Schorr, R., on peat briquettes, 516.  
 Schott, E. A., on metallography, 651.  
 Schraml, F., on gas losses in the open-hearth furnace, 620.  
 Schreiber, on methods of working in mines, 549.  
 Schulte, on electric plant in mines, 547.  
 Schulte, on mine pumps, 553.  
 Schultz, on winding engines, 542.  
 Schulz-Briesen, B., on coal in France, 506.  
 Schulz-Briesen, B., on coal in Germany, 507.  
 Schulz-Briesen, B., on history of coal mining in Essen, 555.  
 Schulz-Briesen, B., on iron ores in Germany, 467.  
 Schumacher, on mine surveying, 555.  
 Schwabe, on iron trade statistics of the United States, 717.  
 Schwarz, C. von, on iron-portland cement, 587.  
 Schwarz, C. von, on wrought iron and cast iron pipes, 674.  
 Scott, H. K., on coal in Brazil, 513.  
 Scott, R. G., on thermal treatment of steel, 90.  
 Screening coal, 557.  
 Seebohm, on the water-flush system in mining, 549.  
 Seger cones, 116, 497, 504.  
 Segregation in steel, 652.  
 Semi-fluid state of metals, 647.  
 Semlitsch, A., on coking brown coal, 521.  
 Semlitsch, A., on German and Austrian coke, 523.  
 Senior, George Edward, elected member, 6.  
 Serlo, on sanitation at mines, 489.  
 Sevieri, Vieri, elected member, 6.  
 Sexton, A. Humboldt, on modern blast-furnaces, 562.  
 Seyler, C. A., on composition of coal, 504.  
 Seymour, R. D., on ore handling, 490.  
 Shaft at Ashland mine, 487.  
 Shaft sinking, 539.  
 Shea, on coal-dust explosions, 554.  
 Shedd, S., on iron ore in Washington, 479.  
 Shedden, Duncan Jones, elected member, 6.  
 Shinn, J. A., on production of blast-furnace slag, 586.  
 Shuler, D. P., on Staph continuous blast-furnace, 566.  
 Siberia, coal in, 509.  
 Sidersky, H., book on metallurgy by, 727.  
 Siede, on shaft-closing devices, 543.  
 Siemens, F., obituary notice of, 449.  
 Siemens electric pyrometer, 118.  
 Siemens water pyrometer, 122.  
 Siemens and Halske, book on metallurgy by, 727.  
 Siemens-Ilgner winding system, 542.  
 Siemann, E., on ore handling, 489.  
 Silicon, determination of, 681.  
 Silicon steel, 659.  
 Simmersbach, B., on coal in the United States, 512.  
 Simmersbach, O., on American iron and coal trades, 717.

- Simmersbach, O., on blast-furnace fuel, 567.  
Simmersbach, O., on modern coke-oven plants, 520.  
Simmersbach, O., on suitable ores for special grades of iron, 586.  
Simon, A., on coal cutting, 548.  
Simonson, A., on small converters, 632.  
Simpson, J. B., on coal in England, 505.  
Simpson, L., on electric smelting of iron ore, 603.  
Simpson, R. R., on shaft-sinking, 539.  
Sjöstedt, E. A., on charcoal kilns, 515.  
Sjöstedt, E. A., on electric production of iron alloys, 606.  
Skrabal, A., on determination of iron, 688.  
Slag, basic, analysis of, 689.  
Slag, basic Bessemer, 636.  
Slag, blast-furnace, 585.  
Slag, ferro-manganese, 678.  
Small converters, 630.  
Small open-hearths for castings, 626.  
Smelting, native iron, 602.  
Smith, C. G., on foundry appliances, 597.  
Smyth, C. H., on iron ore in New York, 478.  
Smith, Enos, elected member, 6.  
Smith, W. S. T., on iron ore in Wyoming, 480.  
Smeysters, J., on coal in Belgium, 506.  
Sneddon, J. B., on oil shale, 530.  
Snelus, G. J., vote of thanks to president, 261.  
Snyder, F. T., on magnetic separation of ores, 494.  
Sohier, A., book on mining by, 731.  
Solids, surface structure of, 647.  
Sonnenschein, A., book on mining by, 731.  
Sonntag, P., on electric power plant in collieries, 547.  
Sørensen, S. O. L., on determination of iron, 688.  
Souder, H., on iron ore in Cuba, 481.  
Sound ingots, production of, 638.  
South Africa, coal in, 511.  
South America, mineral resources of, 712.  
Spain, coal in, 510.  
Spain, mineral statistics of, 713.  
Spain, petroleum in, 526.  
Spanish blast-furnace, 571.  
Special iron alloys, 655.  
Specifications for cast iron, 672.  
Specifications, standard, 672.  
Specifications, steel, 672.  
Spencer, A. C., on manganese ore in Cuba, 482.  
Spurr, J. E., on Lake Superior iron ores, 475.  
Seapelkin, W., book on mining by, 731.  
Stach, on ventilation of collieries, 553.  
Stahl, A. F., on coal in Russia, 509.  
Stainier, X., on coal in Belgium, 506.  
Standard specifications, 672.  
Stanger, Reginald H. Harry, elected member, 6.  
Stanton, T. E., on mine pumps, 551.  
Stapf, T., on gas welding and heating furnaces, 639.  
Stapf continuous blast-furnace, 565.  
Statistics, 691.  
Stead, J. E., member of pyrometer committee, 89.  
Stead, J. E., on explosions produced by ferro-silicon, 37.

- Stead, J. E., on manufacture of pig iron at Herräng, 60.  
Stead, J. E., on pyrometers, 160.  
Stead, J. E., on segregation in steel, 652.  
Stead, J. E., on thermal treatment of steel, 92.  
Steel, basic open-hearth, 623.  
Steel, brittleness of, 655.  
Steel castings, 641.  
Steel castings, strength of, as affected by temperature, 671.  
Steel, cold working of, 640.  
Steel, corrosion of, 676.  
Steel, effect of repeated heating of, 654.  
Steel forgings, 607.  
Steel furnace, crucible, thermal balance of a, 618.  
Steel hardening metals, 718.  
Steel, hardening of, 655.  
Steel, heat treatment of, 653.  
Steel in American building construction, 391.  
Steel, mild, tensile tests of, 669.  
Steel plates, circular, strength of, 672.  
Steel, production of, 617.  
Steel, production of, without scrap or ore, 619.  
Steel, segregation in, 652.  
Steel specifications, 672.  
Steel, tests of, variations in structure and, 668.  
Steel waggons, 645.  
Steel, world's production of, 722.  
Steel, tool, high speed, 642.  
Steger, on coal briquettes, 560.  
Steger, H., on water gas, 537.  
Stein, P., book on mining by, 731.  
Stevens, Samuel Edward, elected member, 6.  
Stevenson, George, elected member, 6.  
Stevenson, G. M., on winding engines, 542.  
Stevenson, J., obituary notice of, 450.  
Stock distribution in blast-furnaces, 562.  
Stockett, L., on coal-breaking machinery, 557.  
Stockton, Joseph Sadler, elected member, 6.  
Stone, E. H., book on mining by, 731.  
Storey, Charles B. O., elected member, 6.  
Stoughton, B., on small converters, 630.  
Strachan, R., on underground temperatures, 539.  
Strain, Hugh, junr., elected member, 6.  
Strength and structure of cast iron, 666.  
Strength of circular steel plates, 672.  
Strength of steel castings as affected by temperature, 671.  
Stress, tensile and repeated, 662.  
Stresses applied to iron and steel, 413.  
Stresses, effect of alternate, 662.  
Stridsberg, F. G., on briquetting iron ore, 495.  
Structural ironwork, 645.  
Structure and tests of steel, 668.  
Structure of cast iron, strength and, 666.  
Structure of solids, surface, 647.  
Stütz, E., on use of thermite for castings, 642.  
Styrian steel, 579.  
Sulphur and oxygen in cast iron, 675.  
Sulphur, determination of, 683, 689.



- Sundgren, E. A., elected member, 6.  
 Sundström, C., on determination of sulphur, 690.  
 Suplee, H. H., book on metallurgy by, 727.  
 Surface structure of solids, 647.  
 Surzycki, Stanislas, elected member, 6.  
 Surzycki, S., on continuous practice in a fixed hearth, 62.  
 Sutcliffe, E. R., on bricks from blast-furnace slag, 596.  
 Sutherland, D. A., on asphalt, 532.  
 Swank, J. M., on rails, 645.  
 Sweden, concentration of ores in, 490.  
 Sweden, iron trade statistics of, 714.  
 Sweden, old blast-furnace ordinance by Queen Christina,  
 Swedish blast-furnaces, 572.  
 Switzerland, iron ore in, 472.  
 Symington, Hugh, elected member, 6.  
 Symington, Thomas, elected member, 6.  
 Synthesis of Bessemer steel, 291.  
 Szajnoch, L., on petroleum in Austria, 524.

## T.

- TACIT, V., on boring for petroleum, 533.  
 Tangye gas producer, 536.  
 Tar as fuel, 622.  
 Taramelli, T., on coal in Italy, 508.  
 Tata, Dorabjee Jamsitjee, elected member, 6.  
 Tata, J. N., obituary notice of, 451.  
 Tatham, Thomas Leonard, elected member, 7.  
 Taube, E. A. B., on iron trade statistics of Russia, 708.  
 Taylor, B., on rails, 645.  
 Taylor gas producer, 536.  
 Teichgräber, on iron ore in Spain, 468.  
 Temperature, influence of variations of, in casting, 420.  
 Temperatures, underground, 538.  
 Tennessee, iron ore in, 479.  
 Tensile and repeated stress, 662.  
 Tensile tests of mild steel, 669.  
 Terbeck, on compressed air in mines, 547.  
 Testing cast iron, 664.  
 Testing machines, 662.  
 Tests of metals, 668.  
 Tests of mild steel, tensile, 669.  
 Tests of steel, variations in structure and, 668.  
 Texas-Louisiana, petroleum in, 529.  
 Theisen, E., on blast-furnace gas, 570.  
 Thermal balance of a crucible steel furnace, 618.  
 Thermal efficiency of the blast-furnace, 211.  
 Thermal reactions in gas producer, 534.  
 Thermal treatment of steel in large masses, 61.  
 Thermite for castings, use of, 641.  
 Tholander, H. E., on Swedish blast-furnaces, 572.  
 Thomas, Alexander Shirreff, elected member, 7.  
 Thompson, A. B., book on mining by, 731.  
 Thompson, G. R., on mine surveying, 556.  
 Thompson, W., on mine drainage, 553.  
 Thompson's calorimeter, 501.  
 Thwaite, B. H., on cleaning blast-furnace gas, 571.

- Thwaite, B. H., on coke in the Hüssener oven, 214.  
 Thwaite, B. H., on pyrometers, 171.  
 Thwaite, B. H., on use of blast-furnace gas, 569.  
 Thwaite, B. H., *paper* on "The use of steel on American lofty building construction," 391; introduction, 391; early history, 392; American development, 394; rationale of the system, 396; important field of application for steel and iron, 400; importance of the knowledge of the system on the part of the manufacturer, 404; the aesthetic system, 406; rapidity of construction, 406; guarding against the effect of steel and iron flame contact, 407.  
 Tideström, C. W., on American open-hearth steel plants, 629.  
 Timbering in mines, 545.  
 Timé, on iron trade statistics of Russia, 711.  
 Timmermans, François, elected member, 7.  
 Tin-plates, manufacture of, 646.  
 Titanium, determination of, 686.  
 Tonkin, iron foundries in, 699.  
 Tool-steels, high speed, 642.  
 Tornau, F., on coal in Germany, 507.  
 Treasurer's report, 17.  
 Treptow, B., on coal in Germany, 508.  
 Trinidad, petroleum in, 526.  
 Trube, Gustave Adolph, elected member, 7.  
 Tube-rolling, 615.  
 Tungsten, determination of, 684.  
 Tungsten ore, 483.  
 Turkestan, petroleum in, 526.  
 Turner, Professor T., book on metallurgy by, 727.  
 Turner, Professor T., on brittleness of steel, 655.  
 Turner, Professor T., on pyrometers, 167.  
 Turner, Professor T., on semi-fluid state of metals, 647.  
 Twelvetees, W. H., book on mining by, 731.  
 Twelvetees, W. H., on oil shale, 530.

## U.

- UZZLING pneumatic recorder, 124.  
 Unckenbolt, on small converters, 632.  
 Underground fires, 554.  
 Underground haulage, 544.  
 Underground temperatures, 538.  
 Unger, M., on mine pumps, 553.  
 Unger, M., on shaft-sinking, 540.  
 United Kingdom, accidents in mines and quarries in, 692.  
 United Kingdom, coal in, 693.  
 United Kingdom, imports and exports of, 692.  
 United Kingdom, iron and steel industries of, 693.  
 United Kingdom, iron ore in, 692.  
 United Kingdom, iron trade statistics of, 691.  
 United Kingdom, mineral statistics of, 691.  
 United Kingdom, open-hearth furnaces in, 692.  
 United States, accidents in collieries in, 719.  
 United States, blast-furnaces in, 575.  
 United States, coal in, 511.  
 United States, iron ore in, 474.  
 United States, iron trade statistics of, 715.  
 United States, manganese ore in, 482.  
 1904.—i.

United States, mineral statistics of, 717.  
 United States, natural gas in, 719.  
 United States, new blast-furnaces under construction, 574.  
 United States, petroleum in, 527.  
 United States, production of iron ores of, 717.  
 United States, production of manganese in, 718.  
 Unwin, W. C., on tensile tests of mild steel, 669.  
 Use of steel in American lofty building construction, 391.  
 Utilisation of blast-furnace slags, 585.  
 Utilisation of coke oven-gases, 519.

## V.

VANADIUM, determination of, 684.  
 Vanadium in coal, 515.  
 Vanadium steel, 659.  
 Vandertaelen, V., on coal in China, 514.  
 Variations in structure and tests of steel, 668.  
 Varley, Reginald Wells, elected member, 7.  
 Varying casting temperatures, influence of, 420.  
 Vattier, C., on coal in the Argentina, 513.  
 Vattier, C., on electric smelting of iron ore, 604.  
 Vattier, C., on manganese ore in Chili, 482.  
 Vattier, C., on mineral resources of South America, 712.  
 Veen, H. J. van der, book on metallurgy by, 727.  
 Ventilation of collieries, 553.  
 Verbo, O. C. von, on endless chain winding, 543.  
 Verity, Joseph, elected member, 7.  
 Victoria, coal in, 510.  
 Victoria, iron ore in, 474.  
 Villain, F., book on mining by, 731.  
 Virginia, coal in, 513.  
 Voelcker, H., book on metallurgy by, 727.  
 Vogt, J. H. L., book on metallurgy by, 727.  
 Vogt, J. H. L., on corrosion of iron and steel, 677.  
 Vogt, J. H. L., on iron ores in Norway, 467.  
 Volk, C., book on mining by, 731.  
 Vredenburg, E., on chrome ore in India, 482.  
 Vredenburg, E., on iron ore in India, 473.

## W.

WADDIE, H. J., on generation and distribution of power, 614.  
 Waggon, steel, 645.  
 Wainwright, J. W., appointed scrutineer, 1.  
 Walker, W., on coal-cutting, 548.  
 Waller, on formation of ore deposits, 463.  
 Walther-Meunier, on faulty boiler plates, 661.  
 Wanner's pyrometer, 140, 504.  
 Ward, H. A., on meteorites, 485.  
 Warman, P. C., on iron ore in the United States, 475.  
 Warne, J. C., on moulding, 599.  
 Warren, W. H., on nickel steel, 659.  
 Warwick, A. W., on testing detonators, 548.  
 Washing and screening coal, 557.  
 Washington, iron ore in, 479.  
 Water gas, 536.

- Waterston, Hugh Crawford, elected member, 7.  
 Waterston, Robert, elected member, 7.  
 Watson, T. L., on manganese ore in the United States, 482.  
 Watts, H. W., on variations in structure and tests of steel, 668.  
 Weber, F. C., on preventing blowholes in ingots and castings, 641.  
 Webster, W. R., on manufacture of eye-bars, 644.  
 Webster, W. R., on physics of cast iron, 663.  
 Webster, W. R., on standard specifications, 672.  
 Wedemeyer, O., on loss of iron in the reverberatory furnace, 593.  
 Wedding, H., book on metallurgy by, 727.  
 Wedding, H., on blast-furnace practice, 562.  
 Wedding, H., on iron trade statistics in Germany, 703.  
 Weeks, Henry Bridges, elected member, 7.  
 Weiske, on structural ironwork, 645.  
 Weiskopf, Alois, elected member, 7.  
 Weiskopf, A., on iron ores in Norway, 467.  
 Weiskopf, A., on iron ore in West Cumberland, 464.  
 Weiskopf, A., on manufacture of pig iron at Herräng, 57.  
 Weiskopf, A., on pyrometers, 185.  
 Welding, electric, 642.  
 Welding, gas, and heating furnaces, 639.  
 Wells, J. W., on magnetic concentration of ores, 493.  
 Wells, J. W., on molybdenite, 482.  
 Wencelius, A., on analysis of minette, 687.  
 Wencelius, A., on iron ore in Switzerland, 472.  
 Wenström separator, 464.  
 Wesel, iron ores in, 466.  
 West, George Frederick, elected member, 7.  
 West, T. D., on foundry practice, 588.  
 West, T. D., on moulding, 598.  
 West Cumberland, iron ore in, 464.  
 Western Australia, coal in, 511.  
 Western Australia, iron ore in, 474.  
 Westgarth, T., on the Hüssener coke oven, 211.  
 Weston, W., on petroleum in Colorado, 528.  
 Wetherill magnetic concentrator, 493.  
 Wex, on mine timbers, 545.  
 Wheeler, Percy, elected member, 7.  
 Wheels, chilled, 645.  
 White, D., on coal in Kansas, 512.  
 White, Sir W., presentation of portrait of, 15.  
 White, Sir W., speech by, 437.  
 Whitehouse, Benjamin, elected member, 7.  
 Whitfield, Charles, elected member, 7.  
 Whitfield's gas producer, 536.  
 Whitwell, W., vote of thanks by, 218, 253, 260.  
 Wiborg thermophone, 146.  
 Wicksteed, J. H., on the evolution of the chain, 579.  
 Widdowson, John Henry, elected member, 7.  
 Wietezynski, M., on petroleum in Austria, 524.  
 Wight, E. S., on mine drainage, 552.  
 Wilcox, Charles, elected member, 7.  
 Wild, Frank Dickinson, elected member, 7.  
 Wilkinson, G., obituary notice of, 451.  
 Wilkins, William, elected member, 7.  
 Willard, Eugene B., jun., elected member, 7.  
 Willey, D. A., on petroleum in Texas, 530.

Williams, David, elected member, 7.  
 Williams, E., on shaft sinking, 539.  
 Williams, W., obituary notice of, 452.  
 Willmott, A. B., on iron ore in Canada, 473.  
 Wilson, G. A., on basic open-hearth steel, 623.  
 Wincott, George P., elected member, 7.  
 Winding appliances, 540.  
 Winding plant at Oliver mine, 487.  
 Winding ropes, 544.  
 Winkel, H., on petroleum in Russia, 712.  
 Winstanley, G. H., on limits of deep boring, 544.  
 Winterthur gas producer, 536.  
 Wisconsin, iron ore in, 480.  
 Witherow, J. P., obituary notice of, 451.  
 Wittman, F., on ferro-manganese slag, 678.  
 Wolff, on peat, 514.  
 Wolff, J. E., on manganese ores in the United States, 482.  
 Wood, M. P., book on metallurgy by, 728.  
 Woodman, Francis John, elected member, 7.  
 Woodward, Robert Guthrie, elected member, 7.  
 Working of steel, cold, 640.  
 World's production of ammonium sulphate, 722.  
 World's production of coal and iron, 720.  
 World's production of steel, 722.  
 Wright, J. B., on steel waggons, 645.  
 Wrought iron and cast iron pipes, 673.  
 Wuester, Gustav, elected member, 8.  
 Wüst, F., on fore-hearths to cupolas, 590.  
 Wüst, F., on limestone in the cupola, 594.  
 Wüst, F., on malleable castings, 599.  
 Wüst, F., on manganese ore in the cupola, 594.  
 Wüst, F., on moulding, 598.  
 Wüst, F., on strength and structure of cast iron, 667.  
 Wüst, F., on thermal balance of a crucible steel furnace, 618.  
 Wynne, F. H., on native iron smelting, 602.  
 Wyoming, iron ore in, 480.

## Y.

YAKOVLEFF, Vladimir, elected member, 8.  
 Yale, T. P. O., on accidents from electricity in mines, 546.  
 Yates, J. A., on petroleum in Kansas, 529.  
 Young, L. E., on coal in Iowa, 512.

## Z.

ZAUBITZ pyrometer, 147.  
 Zenghelis, C. D., book on metallurgy by, 728.  
 Zeppa, P., on petroleum in Italy, 526.  
 Zethelius, Ludwig, elected member, 8.  
 Ziebarth, on coke-oven gases, 519.  
 Zinc in the blast-furnace, 584.  
 Zomboria, S. de, on ore handling, 489.  
 Zuber, R., on petroleum in Austria, 524, 525.





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